ELSEVIER

Urban Energy Transition

From Fossil Fuels to Renewable Power

Edited by Peter Droege

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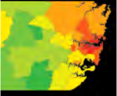

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Barcelona and the Power of Solar Ordinances: Political Will, Capacity Building and People's Participation

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19.1 Introduction: Energy and People Living in Cities

In 1975, 4 billion people lived on Earth – and 38% in cities. At the end of 1999, we were 6 billion and 47% of us were living in cities. But in 2006, according the United Nations, our number had risen to 6.5 billion, with half living in urban environments.

But this is an unsustainable path: in the early 1990s the carbon emissions crossed the threshold of 6 billion tons and in 2003 they were 6.7 billion. At the same time the gross global product was US$ 48.8 trillion (US$ 44 trillion directly linked to the use of fossil fuels). It means that global carbon efficiency was over $7,302/ton C. Japan, one the most efficient carbon economies in the world, had a carbon efficiency of approximately $13,000/ton C and it has a per capita carbon emission of 2.35 tons C/capita/year. If all the present inhabitants on Earth were emitting the same as in Japan, global carbon emissions would be more than 14.6 billion tons, more than twice the present level of emissions. The IPCC recommends a 60–80% reduction and some authors (Byrne *et al*. 1998) have suggested that 2.35 tons CO_2 per capita as a global sustainable emissions level, which is equivalent to about 1 ton of C.

Let us now take a look at the present energy systems (Fig. 19.1). To increase the efficiency of the energy system we need to increase the efficiency of supply technologies (ST) and also to increase the efficiency of end-use technologies (EUT). But a sustainable energy path requires not only technology but also a sustainable lifestyle.

How much electricity was needed to supply minimum domestic energy services (MDES) to urban populations living in 2006?

Assuming the MDES listed in Fig. 19.2, and not considering the non-electric energy services (cooking and heating water), the electricity necessary to supply each family living in cities depends of the end-use technologies the families were using: conventional or energy efficient technologies (Table 19.1). Each family equipped with conventional technologies requires a supply of 7,008 kWh/year, but the use of energy efficient end-use systems

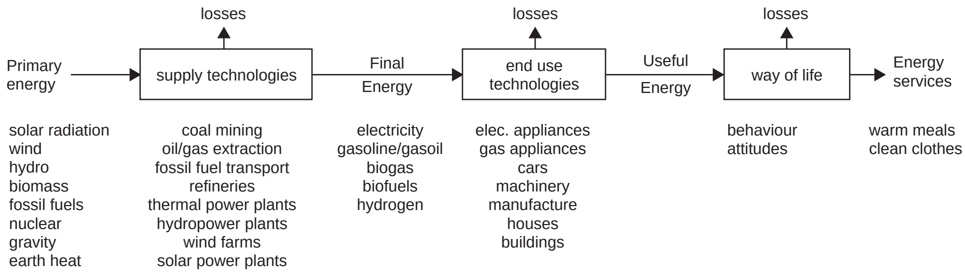

Fig. 19.1. Energy systems: the techno-human chain.
(Source: Norgard 1992).

Energy services	level of energy services (electricity)
Lighting	1.000 lumen average, corresponding to 6 incandescent lamps, each 60 W, operating 6 hours per day.
Refrigeration	200 liter refrigerator (+5°C) and 100 liter freezer (−18°C)
Washing	200 laundry washings per year, each 4 kg, in an automatic electric washing machine. Possible need for warm water is assumed to be provided from non-electrical energy
Electronics	several hours of TV watching, radio listening and computer use every day, as well as other minor uses of electronics
Ventilation	supply of fresh air in high rise buildings plus some unspecified ventilation for cooling
Other uses	several other pieces of electric equipment can be added within this category. Equipment with electric heating should generally be avoided

Fig. 19.2. Minimum domestic electricity service per household.
(Source: Norgard 1989, 1991).

reduces its demand to only 1,226 kWh/year. On a yearly basis the average power choice is between 800 watts and only 140 watts. This means 200 W/capita – or only 35 W/capita.

According the United Nations the urban population was 3.27 billion in 2006. To cover the MDES for the entire urban population in 2006, it required 5,729 TWh/year or only 1,003 TWh/year, depending on the type of end-use technology in use.

How is this energy to be supplied? Before answering this question, let us take a look at supply technologies.

Using conventional coal thermal power plants (steam turbine, efficiency 36%) one will need 1,022 or 179 units, 800 MW each with a capacity factor – CF – of 0.8, depending on whether consumers were using conventional or energy efficient end-use technologies. The resulting emissions will be the ones listed in Table 19.2.

If the electricity is generated with combined cycle gas turbines (steam and gas turbines, efficiency 53%), in this case one will need 4,088 or 715 units, 200 MW each (with a CF of 0.8). The associated emissions are listed in Table 19.2.

Table 19.1. Urban world, 2006: supply and end-use technologies.

Number of fossil fuel power plants, SO_2 NO_x and CO_2 emissions

	WORLD 3,270,000,000			**Supply technology** conventional Coal thermal power plant (steam turbine, 36%)				
		W/cap	TWh/year	number plants	Capacity MW	SO_2 mtn	NOx mtn	CO_2 mtn
End-use	conventional	200.00	5,729.04	1,022	800	98.54	7.39	5,064.47
technology	efficient	35.00	1,002.58	179	800	17.24	1.29	886.28

				efficient Comb. cycle power plant (gas + steam turbine, 53%)				
		W/cap	TWh/year	number plants	capacity MW	SO_2 mtn	NO_x mtn	CO_2 mtn
End-use	conventional	200.00	5,729.04	4,088	200	0.00	0.57	1,976.52
technology	efficient	35.00	1,002.58	715	200	0.00	0.10	345.89

Nuclear power plants, radioactive emissions, spent fuel (Pu content), yellow cake, uranium ore, liquid and solid wastes

				Supply technology Nuclear power plant								
		W/cap	TWh/any	number reactors	capacity MW	Emissions air + water Bq*10^{12}	Spent fuel ton	Pu spent fuel kg	U_3O_8 yellow cake ton	Uranium ore ton	Liquid wastes ton	Solid wastes ton
End-use	conventional	200.00	5,729.04	818	1,000	54,426	20,438	163,500	155,325	212,550,000	367,875,000	245,250,000
technology	efficient	35.00	1,002.58	143	1,000	9,525	3,577	28,613	27,182	37,196,250	64,378,125	42,918,750

Number of SEGSth AND WECS, SO_2 NO_x and CO_2 emissions

				Supply technology SEGSth		WECS		clean and renewable solar/wind/biomas/hydro		
		W/cap	TWh/any	Capacity GW	Surface km^2	Capacity GW	Surface km^2	SO_2 mtn	NO_x mtn	CO_2 mtn
End-use	conventional	200.00	5,729.04	1,869	36,063	2,180	87,200	0.00	0.00	0.00
technology	efficient	35.00	1,002.58	327	6,311	382	15,260	0.00	0.00	0.00

Table 19.2. Barcelona, 2005: supply and end-use technologies (domestic sector).

Thermal power capacity, SO_2 NO_x and CO_2 emissions 2005

Supply technology

BARCELONA 1,605,502	year 1997			conventional Coal thermal power plant (steam turbine, 36%)				
		W/cap	GWh/year	Number plants	Capacity MW	SO_2 mtn	NO_x mtn	CO_2 mtn
End-use technology	conventional	200.00	2,812.84	1	401	48.38	3.63	2486.55
	efficient	35.00	492.25	1	70	8.47	0.63	435.15
	real (2005) (*)	205.25	2,887.30	1	412	49.66	3.72	2552.37

(*) domestic

				efficient Comb. cycle power plant (gas + steam turbine, 53%)				
		W/cap	GWh/year	Number plants	Capacity MW	SO_2 mtn	NO_x mtn	CO_2 mtn
End-use technology	conventional	200.00	2,812.84	1	401	0	0.28	970.43
	efficient	35.00	492.25	1	70	0	0.05	169.83
	real (2005) (*)	205.25	2,887.30	1	412	0	0.29	996.12

Nuclear power capacity, radioactive emissions, spent fuel (Pu content), yellow cake, uranium ore, liquid and solid wastes

		W/cap	GWh/year	Nuclear power plant Number reactors	Capacity MW	Emissions air + water Bq*10^{12}	Spent fuel ton	Pu spent fuel kg	U_3O_8 yellow cake ton	Uranium ore ton	Liquid wastes ton	Solid wastes ton
End-use technology	conventional	200.00	2,812.84	0.40	1,000	26.72	10.03	80.28	76.26	104,358	180,619	120,413
	efficient	35.00	492.25	0.07	1,000	4.68	1.76	14.05	13.35	18,263	31,608	21,072
	real (2005) (*)	205.25	2,887.30	0.41	1,000	27.43	10.30	82.40	78.28	107,120	185,400	123,600

Renewable energy capacity, SO_2 NO_x and CO_2 emissions

		W/cap	GWh/year	SEGSth Capacity MW	Surface km^2	WECS Capacity MW	Surface km^2	clean and renovable solar/wind/biomas/hydro SO_2 mtn	NO_x mtn	CO_2 mtn
End-use technology	conventional	200.00	2,812.84	917	17.71	1,284	12.84	0	0	0
	efficient	35.00	492.25	161	3.10	225	2.25	0	0	0
	real (2005) (*)	205.25	2,887.30	942	18.18	1,318	13.18	0	0	0

If the decision is to supply the electricity with nuclear power plants, in this case one will need 818 or 143 units, 1,000 MW each (CF: 0.8), but they will produce thousands of tons of spent fuel (more than 20,000 tons or 3,500 tons) containing significant quantities of plutonium (164 tons or 29 tons) and they will introduce huge quantities of radioactivity into the biosphere (54 or 10 quatrillion becquerels). Also they will need to mine huge quantities of uranium ores (212 or 37 million tons) to produce the yellow cake (155 or 37 tons) needed to fuel the reactors. In Table 19.2 are listed the quantities of uranium ores, yellow cake and solid and liquid wastes (containing 85% of radioactivity from the ores).

But if the electricity is generated using renewable energy sources, the electric system will not have any emissions at all. What will be the requirements for producing that electricity with renewable energy technologies? A comparison of technologies produces interesting figures. The selected technologies are established and being commercialized: Solar Energy Generating Systems (SEGS), like those in the Mohave Desert, California, and Wind Energy Conversion Systems (WECS), like ones now operating in many places of the world. In the case of SEGS, it will be necessary to install 1,869 GW of capacity or only 327 GW, but 36,063 km^2 or 6,311 km^2 will be needed – at a capacity factor of 0.35, and 1.93 Ha/MW. In the case of WECS, it will be necessary to install 2,180 GW or 382 GW, and the surface needed will be 87,200 km^2 or 15,260 km^2 (CF=]0.3, and 4 Ha/MW). But using modern WECS in the megawatt range with a needed area of 1 Ha/MW, the total surface needed will be 21,800 km^2 or 3,815 km^2. See Table 19.2 for more details.

19.2 The Real Case of Barcelona: The Energy Needs and the Energy Supply

But what is happening in a real and concrete city? The example of Barcelona is instructive.[1] Figure 19.3 shows the non-renewable energy flow for Barcelona at the second half of the 1990s. The city imported a large fraction of energy it used in the form of electricity, gas (NG and LPG), petrol and diesel. And the city was producing waste, half of it organic. Since 1973 all the waste was deposited in a big landfill (Garraf) and burned in an old incineration plant, only adapted to control emissions in the early 21st century. Also, because the electricity the city was using came from nuclear power plants, an enormous amount of radioactive waste was generated. The city also generated copious amounts of greenhouse gases (CO_2 and CH_4).

Looking at Barcelona at the end of 20th century, one can see that the city was essentially serviced by non-renewable energy inputs. The figures in 1997 were:

- Electricity: 5,360 GWh
  - Imports: 4,851 GWh
  - Local generation: 456 GWh
  - Incineration plant: 53.7 GWh

[1]All the data about energy in Barcelona stem from *BarnaGEL – Barcelona Grup d'Energia Local. BarnaGEL* was the local energy agency created with European funds in 1995; it operated until 2000. In that year the councillor responsible for energy policy terminated the support of *BarnaGEL*, apparently because it operated outside the municipality's control. Instead, a new organization under the direct management of the city was created. Since then, the city's performance appears to have weakened, both in terms of efficiency and in the introduction of renewables, illustrating the importance of perseverance and continuity in political leadership. The data about capacities of power plants needed to supply Barcelona derive from the author's lecture notes on energy at the Autonomous University of Barcelona.

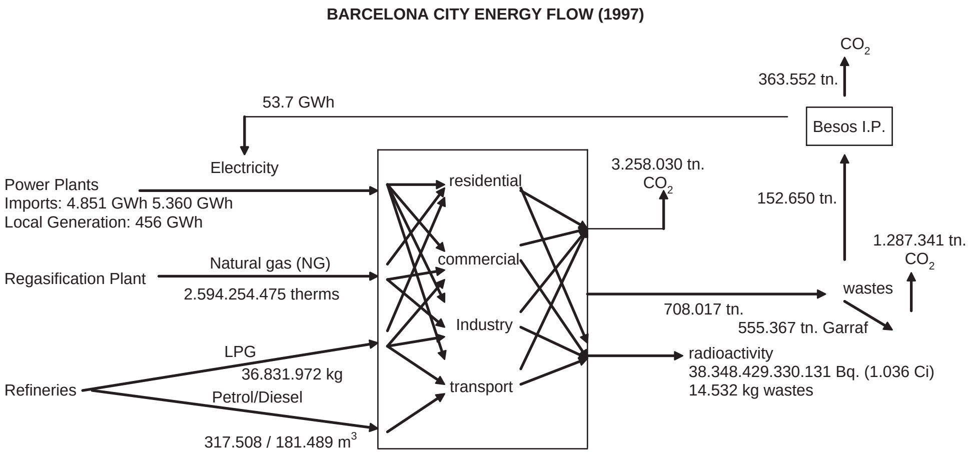

Fig. 19.3. Barcelona city energy flow (1997).
(Source: *BarnaGEL* 1999).

- Natural gas (from a regasification plant): 2,594,254,475 therms
- Liquefied petroleum gases (from refineries): 36,831,972 kg
- Petrol (from refineries): 317,508 m^3
- Diesel (from refineries): 181,489 m^3.

At that time Barcelona produced non-renewable outputs, related to energy (1997). The figures were:

- Municipal wastes: 708,017 tons
  - To landfill: 555,367 tons
  - To incineration: 152,650 tons
- CO_2 emissions: 4,980,923 tons
  - From landfill: 1,287,341 tons
  - From incineration: 363,552 tons
  - From energy uses: 3,258,030 tons
- Radioactivity (from electricity generation):
  - Emissions: 1,036 curies (38 trillion becquerels)
  - Waste: 14,532 kg.

But Barcelona's land area also receives huge quantities of solar energy: ten times more than the energy the city consumes, or 28 times more than the electricity it uses. The sun over its roofs and terraces alone provides 15 times more energy than the electricity it needs. Also the waste the city produces is a potential source of energy: in energy terms the organic wastes produced by the city represent a quarter of the NG consumption of the city, if the organic fraction of municipal solid wastes mixed with the liquid organic wastes were digested with anaerobic systems in methanization plants. See in Fig. 19.4 the renewable energy flow in the city.

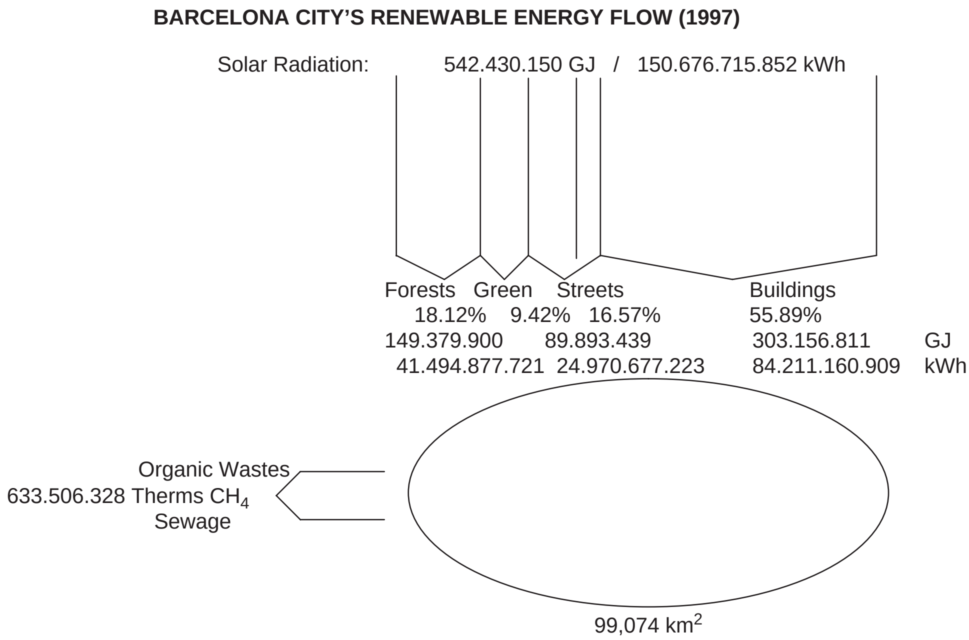

Fig. 19.4. Barcelona city's renewable energy flow (1997).

The Barcelona renewable energy inputs are:

- Solar radiation over the city limits: 542,430,150 GJ or 150,676 GWh.
- Over the buildings: 303,156,811 GJ or 84,211 GWh.
- Over the streets: 89,893,439 GJ or 24,970 GWh.
- Over the green spaces and forests: 149,379,900 GJ or 41,494 GWh.
- CH_4 from organic wastes and sewage: 633,506,328 therms.

In the real case of Barcelona, the domestic electricity consumption was 1,348 GWh/year (1998). On an annual mean base it represented 102 W/capita, three times more than the electricity required if Barcelona families were using efficient end-use technologies (35 W/capita) or half than that required if they were using conventional end-use technologies (200 W/capita). But in 2005 the families living in Barcelona crossed the level of 200 W/capita – doubling electricity consumption when compared to 1998, or 2,887 GWh/year.

To supply this electricity using conventional coal fired thermal power plants (steam turbine, at an efficiency of 36%) or combined cycle power plants (using both steam and gas turbines at an efficiency of 53%) it would be necessary to have 400 MW or only 70 MW of installed capacity (with a capacity factor of 0.8), depending on whether people were using conventional or energy efficient end-use technologies. The resulting emissions will be the ones listed in Table 19.3.

If Barcelona were to decide to supply the electricity with nuclear power plants, in this case it would need the same capacity, but they would produce several tons of spent fuel containing plutonium and radioactivity into the biosphere. Also they would need to mine hundreds of thousand of tons of uranium ore to produce the yellow cake needed to fuel

Table 19.3. Supplying green electricity to Barcelona.

	Electricity consumption (2005)	SEGS		SEGSPV		WECS	
	GWh	MW	km^2	MW	km^2	MW	km^2
Total	7,206.60	2,350	45.36	3,268	32.68	3,291	32.91
Domestic	2,887.30	942	18.18	1,309	13.09	1,318	13.18
Com./ind.	4,319.30	1,409	27.19	1,959	19.59	1,972	19.72
Transport	1,051.00	343	6.62	477	4.77	480	4.80
Capacity factor		0.35				0.25	
Ocupation	Ha/MW	1.93		1		1	
Efficiency				0.15			
Radiation	kWh/m^2.year			1,470.1			

the reactors. Table 19.3 lists the quantities of uranium ores, yellow cake and solid and liquid wastes – those containing 85% of radioactivity from ore.

But by generating the electricity with renewable energy sources the city of Barcelona would not have any of these problems. What will be the requirements to supply the minimum domestic energy services in Barcelona with SEGS and/or WECS in three different scenarios: the real electricity consumption of the city, if people were using conventional and if people were using efficient end-use technologies?

To cover the real domestic consumption with SEGS it will be necessary to install 942 MW (needed surface: 18 km^2). And with WECS, 1,318 MW (needed surface: 13 km^2).

To cover the minimum domestic energy services with SEGS it will be necessary to install 917 MW of capacity or only 161 MW (depending on the end-use technologies the people were using: conventional or efficient), but they will need 18 km^2 or 3 km^2 (capacity factor = 0.35, and 1.93 Ha/MW).

To cover the minimum domestic energy services with WECS, it will be necessary to install 1,284 MW or 225 MW, and the surface needed will be 13 km^2 or 2 km^2 (capacity factor = 0.25, and 1 Ha/MW).

The surface required in all the cases is only a small fraction of the city surface (100 km^2). See Table 19.3 for more details.

If all the sectors (not only the domestic sector) of the city of Barcelona were to be supplied with 100% green electricity (7,207 GWh/year) it would require 2,350 MW of SEGS (45 km^2 or half the city surface) or 3,291 MW of WECS (33 km^2 or one third of the city surface). If it were to supply all the electricity consumed by the city with PV solar electricity it would be necessary to install 3,268 MW (33 km^2). See in Table 19.4 the requirements to supply different sectors. It is interesting to note that with less than 10 m^2 of PV panels it is possible to supply all the electricity one family consumes in Barcelona.

If the city wants to cover its sanitary hot water needs with the sun, what will be the requirements? In a normal year Barcelona consumes 1.02 billion kWh to heat water (636 million with NG and 384 million with electricity). To heat all the sanitary water the city is using, it will be necessary to cover only 1.7 km^2 of the surface, which means 1 m^2 per person, 2.5 m^2 per apartment or 21 m^2 per building, and all these surfaces are available in most of the buildings of the city.

And the city has the necessary space to make it possible. A study conducted in 1999 across all of Barcelona's neighbourhood typologies, shows that between 19 and 43 m^2 of terrace are available for each existing apartment (Fig. 19.5 and Table 19.5).

Table 19.4. Typologies of neighbourhoods (sample).

Name of neighbourhood	Surface of house (m^2)	Surface of terrace (m^2)
Barceloneta	74	19
besos	55.14	14.3
Eixample	100	20
Eixample marítim	100	18
Gràcia	70.5	20
A*8	133	43

Source: Barcelona City Council.

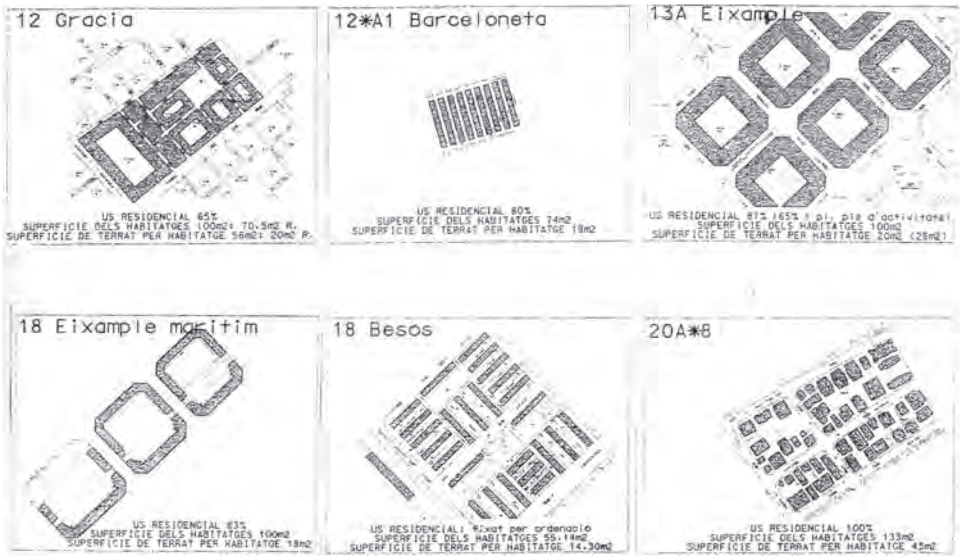

Fig. 19.5. Selection of typologies of different neighbourhoods in Barcelona.

The conclusion is that in a Mediterranean city like Barcelona it is possible to reduce the present energy consumption using the most efficient end-use technologies currently available and it is also possible to generate all the energy the city is using at a local level from renewable energy sources.

19.3 Inefficient and Obsolete Energy Systems

The autonomous community of Catalonia, and its capital Barcelona, inherited a highly inefficient energy system from the Franco regime. But the democratic system built since the dictator's death in 1975 has been unable to modernize the energy system. It is still heavily centralized, based on a few big power stations, fossil or nuclear based, with no cogeneration capacity.

Renewal was started some years ago, building combined cycle gas power plants (CCGPs), but none of these new plants have cogeneration systems to recover the heat lost to the

Table 19.5. Progress on solar thermal in Barcelona.

	1995	1998	1999	Jul-00	Aug.2001	Dec.2001	Jun-02 (m^2)	Dec.2002 (m^2)	Buildings (number)
Residential						3,145	6,425.73	8,130.41	108
Hotels						1,745	2,114.72	2,071.67	20
Sports facilities						972	1,458.00	1,822.00	5
Hospitals						307	349.21	545.71	7
Other						152	421.10	1,458.10	19
Total	700	1,181	1,350	1,632	5,233	6,321	10,768.76	14,027.89	159
Number buildings						65		159	
Residential						3,145	6,425.73	8,130.41	108
Hotels						1,745	2,114.72	2,071.67	20
Sports facilities						972	1,458.00	1,822.00	5
Hospitals						307	349.21	545.71	7
Other						152	421.10	1,458.10	19
Total	700	1,181	1,350	1,632	5,233	6,321	10,768.76	14,027.89	159
Number buildings						65		159	

	Dec.2003 (m^2)	Buildings (number)	Dec.2004 (m^2)	Buildings (number)	Dec.2005 (m^2)	Buildings (number)
Residential	12,821.22	168	14,764	243	19,451	315
Hotels	2,416.71	24	5,641	47	6,150	56
Sports facilities	2,125.50	7	2,200	8	2,545	11
Hospitals	545.70	7	549	7	957	9
Other	1,684.24	26	1,378	22	1,975	36
Total	19,593.37	232	24,532	327	31,078	427
Number buildings	232		327		427	

Source: BarnaGEL and Barcelona City Council.

biosphere (40% of all the heat content in the fuel), when this heat could provide heating and cooling to city users. It is stunning that at the beginning of 21st century the main Spanish utilities (Endesa, Iberdrola and Gas Natural) are building CCGPs without cogeneration, and even more astonishing is that the public authorities authorize them without resistance. Recently two of these utilities (Endesa and Gas Natural) built two CCGPs, just into the Metropolitan Area of Barcelona (more than 3 million inhabitants), with an electric capacity of 788 MW (394 MW each). Neither plant has a cogeneration system, despite their dumping more than 500 MW of heat to the Mediterranean Sea (this is the equivalent of all the heating needs of Barcelona).

This system has more than 46,000 km of high voltage lines and more than 52,000 km of low voltage lines, and the associated losses are more than 3.5 billion kWh/year (almost 10% of all the electricity generated in Catalonia).

The nascent decentralized energetic system, efficient, clean and renewable it will not {AQ1} imposed from one day for the other one. There will be a period of transition, the length of which will depend on the political will that those managing the public affairs manifest. And this political will will only materialize if the citizenship exercises actively their energy responsibilities, in a frame where their basic energy rights have been recognized.

In this transition period, fossil fuels will still be used, but they will be only the less pollutant fossil fuel (fossil natural gas), used with the maximum possible efficiency (decentralized technologies of combined heat and power, providing heating and cooling needs), as long as the big thermal power plants based on coal and nuclear continue to be abandoned.

In order to establish a decentralized or distributed energy system in ways that are efficient, safe, clean and renewable, it is important to recognize a set of basic energy rights:

- 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 manifest themselves in the place where one lives.
- The right to generate one's own energy.
- The right of 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 of generating energy with the most efficient and clean generation technologies available.
- The responsibility to use the most efficient end-use technologies available.
- The responsibility of conservation: of using the generated energy with common sense and avoiding any kind of waste.
- The responsibility of limiting oneself in the use of any form of energy.
- The responsibility of 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 should give absolute priority. Exercising these responsibilities should be considered the fundamental duty of the responsible persons who depend on the sun as a source of energy. Adapting the 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 to be able to sustain life and prosperity on Planet Earth.

19.4 Realizing Energy Efficiency and Renewable Energy Potentials

What would be necessary to realize both the energy efficiency and renewable energy potentials of the cities of the world? The author's experience as an energy engineer active since the late 1970s, but also as a grassroots activist working with non-government organizations (NGOs), was heightened by his insight into political realities when he served as Sustainable City Councillor in Barcelona (between 1995 and 1999). It showed him that three conditions must come together. The first one is political will. Without political commitment no progress will occur in either energy efficiency or renewable energy transitions. Barcelona's decision to adopt the world's first Solar City Ordinance demonstrates this. How was the political will built that made it possible to adopt a solar ordinance? Many factors contributed. First, personal relations and attitudes are extremely important. These,

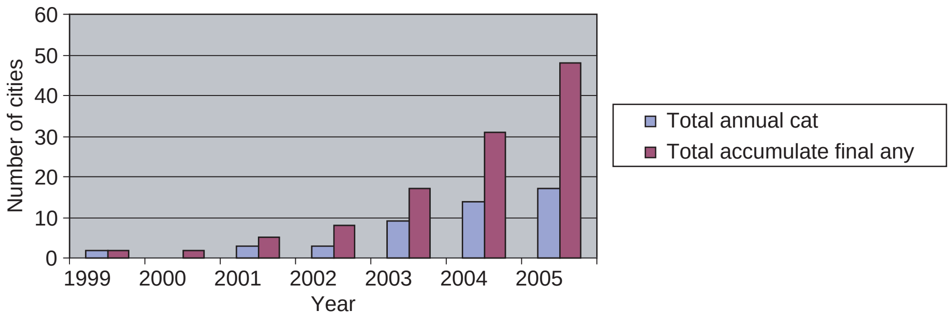

Fig. 19.6. Solar ordinances in Catalonia.

combined with political leadership, based on experience about the decision it is proposed to adopt, can be a good recipe to succeed. Second, it is necessary to have technical capacity. Political commitment alone does not suffice; superb technical ability and skills to bring about and implement change are also needed. In Barcelona, some people from the city management bodies were not convinced at all when the process started. But the work done within the Civic Table on Energy was essential to convince the sceptics. Also, *BarnaGEL*, organizing the Sustainable Energy Forums, helped to make visible solar and renewable energy companies to citizens and politicians. The third condition is people's involvement and public participation. In Barcelona, some local NGOs have been active in the energy field since the early 1980s, helping to create an environment favourable to solar energy. Without the participation of all the city actors (decision-makers, companies, local citizens), it will be difficult to transform the present energy path (hard energy path) to a soft energy path (efficiency + renewables).

These three preconditions for success mandated the building of partnerships between local politicians, technical expertise, business and ordinary citizens.

In Barcelona, between June 1995 and May 1999, a committed group of people worked hard to open the door to urban energy sustainability. The results of this work were an increase of 93% of the surface devoted to collect the energy from the sun for heating water and an increase of 2,400% of the surface devoted to collect the sun's energy and transform it into electricity. In this period of time the solar thermal collectors increased from 700 to 1,350 m^2 and the PV panels from 80 to 2,400 m^2. And this has been only the beginning. All the process resulted in a new trend: the continuous increase of solar energy in Barcelona (see Fig. 19.6).

Why did this happen? What were the local circumstances that made possible this step forward to open the door to energy sustainability in a Mediterranean city like Barcelona?

The municipality of Barcelona receives from the sun ten times the energy the city is consuming in a year – or 28 times its yearly electricity consumption. Despite these facts, before 1995 the city never took seriously decisions to push for solar energy.

An interesting set of circumstances came together to make this happen. On the one hand, as a result of the 1995 municipal elections the government of the city adopted sustainability as an issue. On the other hand, some local NGOs active on energy efficiency and renewables had been organizing events around energy (conferences, campaigns, exhibitions, etc.) since early 1990s in complicity with local companies working in the field. In this way, political commitment, together with social pressure and technical capability, united to start walking on the path of soft energy.

The 1995 municipal elections in Barcelona resulted in a new coalition, where a Green Party candidate was appointed for the first time in the city's history. The new government was based on a political agreement that included the creation of a new political post (the Sustainable City Councillor) and the commitment to push programs for the development and diffusion of renewable energies. Also the 1996–1999 Municipal Action Plan included a series of concrete measures to make possible the use of the solar energy in the city. Between the measures there were the following:

- The use of renewable energies in the municipal buildings.
- To give incentives for using renewable energies in the domestic and services sectors.
- To incorporate solar hot water systems in the municipal buildings and sports facilities.

On 22 April 1998 the Plenary Session of the City Council adopted a political decision on energy sustainability. This decision included the promotion of energy efficiency, the use of renewable energies, the provision of information to the citizens and the cooperation with other local energy actors.

To implement these policies the municipality made use of two key instruments: the Civic Table on Energy (*Taula Cívica de l'Energia*) and the Local Energy Agency (*BarnaGEL – Barcelona Grup de Energia Local*).

The Civic Table on Energy was a municipal structure created in 1994 as a result of a public hearing on environment and energy forced by a coalition of local NGOs. This body involved local officials and staff from different departments of the city council with a local representative of an NGO energy platform, Barcelona Saves Energy (*Barcelona Estalvia Energia – BEE*). Its main objective was to build complicities on energy matters from all people in different departments of the city council. Between 1995 and 1999 the author served as chairman of this body.

BarnaGEL was the result of an EU-PERU project (1994) when Leicester City Council (England) and the Metropolitan Area of Barcelona decided to apply for EU funds to create local energy agencies, with the assistance of Ecoserveis (a local NGO working professionally on energy and environment) and with the collaboration of *ICAEN* (Regional Energy Agency of Catalonia) and *UAB* (Autonomous University of Barcelona). *BarnaGEL* was partially funded by the European Commission between 1996 and 1999. When the project was accepted for funding by the EU the city of Barcelona was not involved in it. Only after the work by the Sustainable City Councillor was done did the city begin working on the project. *BarnaGEL* has been a key facilitator and leader, inspiring all the energy efficiency and renewable energy projects in operation or in construction in Barcelona city. The main objective of *BarnaGEL* has been to build complicities between local actors in order to develop energy projects in the city. *BarnaGEL*, according the European Commission guidelines, was created as an independent body in order to be free to activate all local energy actors .

Also the city of Barcelona was engaged during this time with two more active European networks working on energy in cities: *Energie-Citós* and Climate Alliances.

But the more relevant and well-known energy project has been the Barcelona Solar ordinance, now internationally recognized and awarded with the European Solar Prize 2000.

This very innovative solar law, called 'Barcelona Ordinance on Application of Solar Thermal Energy Systems into the Buildings' or 'Barcelona Solar Ordinance' in brief, enforces all the new buildings to be built in Barcelona (and all the integrally retrofitted buildings) to have solar thermal water systems to cover 60% of sanitary water heating needs.

This Ordinance was adopted by the Plenary Session of the Council in July 1999 and has been mandatory since 1 August 2000. This is a clear example of how to develop renewable energy policies and strategies within a city.

It all started when the Sustainable City Councillor knew that Berlin was working to adopt a Solar Ordinance in 1996. Then the Sustainable City Councillor asked himself a simple question – why was solar energy not widely used in Barcelona, despite the available resource (the sun: 2,351 hours/year, 1,470 kWh/m² · year), the city's energy needs (the city was heating the sanitary water using natural gas and electricity – 1.02 TWh/year) and its available surface (between 19 and 43 m^2 of terrace available for each existing apartment)?

When the process to adopt the Solar Ordinance started, some critics said: 'a city like Barcelona has no power to implement a local law on solar energy', but the supporters replied: 'we will proceed and see what will happen'. At the end no one offered strong opposition and the Solar Ordinance was adopted, not only by the city of Barcelona, but by many more cities in Catalonia and in Spain. At the end of 2005, almost 50 municipalities had adopted it in Catalonia (Fig. 19.6) and 25 all over Spain.

All those facts forced the regional government of Catalonia and the Spanish government to react. As a result, in February 2006, the Catalan government enacted a decree on ecoefficiency in buildings (all the new or integrally retrofitted buildings, consuming more than501/day of hot water (60°C), must have a solar heating system to cover between 40 and 70% depending on the climatic zones). And in March 2006, the Spanish Council of Ministers adopted the new Technical Building Code (*'CTE – Código T[wea]cnico de la Edificación'*) – it is one of the three documents for implementing European Directive 2002/91/CE on Energy Efficiency on Buildings – which establishes basic quality requirements for buildings, and between them, energy requirements (minimal solar contribution for sanitary hot water in all types of new buildings and minimal PV contribution for electricity in some commercial buildings).

The story of the Barcelona Solar Ordinance is a clear case that shows how a proposal considered 'impossible' became a reality in a short period of time!

Opening the door to solar energy in a city like Barcelona was possible with a broad range of small actions and renewable energy projects in order to visualize real action from a municipality. The following contains a brief description of some projects developed under the Barcelona Sustainable City Councillors' Office which started during the 1995–1999 period:

- A PV solar roof at the two main buildings of Barcelona City Hall. It was an EU Thermie project ('A Grid-Connected and Integrated PV System in the Central Buildings of the Barcelona City Hall') to install 1,000 m^2 of PV, 100 kWp power on top of the two most representative buildings of the municipality. At present, the PV roofs on both buildings are in operation (400 m^2, 40 kWp in the first one and 600 m^2 and 60 kWp in the second one). To build the solar roof in the second building it was necessary to deconstruct a 12 floor building and transform it to an eight floor one before covering it with a solar roof. The production of electricity is 170 MWh/year.
- 'Urban ECOTREL – End-user Configuration Offer for Technical solutions on Renewable Energies on-Line'. This was an EU ALTENER project and consisted of a renewable energy information system on urban environments, CD-Rom based, addressed to local officers (political and technical). This package was sent to more than 500 municipalities all around the Catalonia region of Spain and more than 1,000 have been given free of charge to all interested people.
- A full-scale demonstration of a solar house during the 14th European Photovoltaic Solar Energy Conference and Exhibition (Barcelona, 30 June–4 July 1997).

- The solar/wind efficient caravan: this is a mobile facility equipped with solar systems (thermal and PV), a small wind system and energy efficient appliances. This equipment is now being used in and around Barcelona to show in real operation how a house could run with renewables and energy efficient appliances.
- The Sustainable City Resources Center: a municipal fixed facility equipped with a permanent exhibition with energy efficient devices and appliances and renewable energy devices. The name of this facility is '*Oficina de Recursos per la Ciutat Sostenible – ORCS*' (Sustainable City Resources Office) and has been open to the public, free of charge, since May 1999.
- An agreement between city and regional governments in order to make possible the construction of the first PV school in Barcelona (30 kWp power, 38 MWh/year of estimated production). At present there are many schools equipped with solar PV systems.
- An agreement between city council, manufacturers and installers of solar thermal systems in order to incorporate solar thermal water systems in all the existing municipal sports facilities. The two first installations (*Poliesportiu Torrent de Melis* with 74 m^2 of solar collectors and *Piscina Bon Pastor* with 80 m^2) are demonstrating that more than 75% of energy consumption is being covered by solar energy. Now all the new sports facilities are equipped with solar thermal systems.
- A project to make it possible for more than 450 new apartments to be equipped with solar thermal water systems (totalling 609 m^2 of collectors). The apartments were built by the '*Patronat Municipal de l'Habitatge*' (the municipal body charged with social housing construction).This first development has been, and is, quite successful and the users are young people renting (with low rents) the apartments. Also the apartments have incorporated low energy appliances, water saving devices, recycled materials, recycling facilities, etc. By now all the new public owned apartments are incorporating solar thermal systems.
- A municipal policy to give subsidies to solar energy users – thermal and PV – in the city (direct financial subsidies up to 25% of the costs of installation in existing buildings).
- Efficient lighting systems at the City Hall buildings. In October 1995 the City Council decided to replace all incandescent lamps in the City Hall buildings and, in April 1998, all the old fluorescent lighting systems in a main City Hall building – eight flats. The savings have been more than 250,000 kWh/year.
- Biogas valorization from organic waste component: *in-situ* demonstration of the valorization of landfill gas to fuel a car (Garraf landfill, 21 May 1997). Subsequently, the Barcelona Metropolitan Area adopted a Municipal Waste Management Plan that incorporates the construction of three methanization plants (75,000 tons each) to digest the organic fraction of municipal wastes.

All the projects listed above would not be a reality without the complicity of a number of people involved in sustainable energy: local NGOs, experts, companies, etc.

In order to show some of the complicities built around the projects, below is a list of the most relevant actions concerning renewable energy undertaken by local actors with the support of the Sustainable City Office (1995–2000):

- *The Sustainable Energy Forum* organized by *BarnaGEL* – Barcelona Local Energy Group (the local energy agency, EU SAVE program). Three editions have been organized (12–14 March 1998, 25–27 February 1999 and 26 April 2000). During these forums *BarnaGEL* presented the 'Sustainable Energy Green Pages', an electronic catalogue of energy efficiency and renewable energy products and services. *The Sustainable Energy Forum* is currently in its 9th edition.

- Local NGOs Solar Campaign, called *BarnaMIL* (Barcelona thousand) with the goal to achieve 1,000 m^2 of new solar thermal water systems in private existing buildings before the year 2000. This was a campaign started with the involvement of an NGOs Platform, the professional association of renewable energy professionals – APERCA – and the local energy agency – *BarnaGEL*. Now *BarnaMIL* is a local NGO pushing for renewable energy projects in the city.
- The first small PV installation connected to the local grid. This solar PV system (18 m^2, 2.3 kW) is privately owned by *Fundació Terra*, a Barcelona-based NGO devoted to environmental education. This system was built after having being issued by the Spanish Renewable Energy Feed-in-Tariff (*Real Decreto 28/1998*). The PV system was inaugurated on February 1999 in the presence of Barcelona Mayor Joan Clos and the Sustainable City Councillor. The event had a big impact on the media. In 2007, *Fundació Terra* launched the first project in Spain to build a solar PV roof on top of a municipal market, owned by local citizens.
- The *Sole PV* mobile Greenpeace power plant connected to the City Hall grid: this was the Greenpeace Spain campaign to show how a PV solar system could be connected to the grid. The *Sole PV* station was installed in the square where the City Hall is located and was connected to the City Hall grid. As a result, for the first time in Barcelona the municipal buildings were supplied by 'green' electricity.
- The Xth, XIth, XIIth and XIIIth editions of the *Catalonian Conferences for a Non Nuclear and Sustainable Energy Future*, organized by the Group of Scientists and Technicians for a Non Nuclear Energy Future, a well-established NGO working in the field since the late 1970s. These conferences have the support of a wide range of Catalonian NGOs and local renewable energy companies. In all editions of the conferences (now in the 21st edition) distinguished energy specialists have been invited to contribute.
- The Earth Day activities – principally the Earth Fair where renewable energy equipment is shown in an open space to the general public. The Earth Fair has been organized since 1996 by Earth Day Catalonia (a local NGO) in a public garden-park and each fair has been visited by tens of thousands of visitors. Since the 2004 fair, all the electricity needed by the event has been supplied by renewable energy sources (100% biodiesel). In 2007 the Barcelona Earth Fair was in its 12th year.

19.5 The Future

The experience of Barcelona, like other cities in the world, shows us that putting together political commitment, capacity building and people's participation is the recipe that any city needs to start changing the way energy is generated and used.

Important work commenced between 1995 and 1999 in the city of Barcelona will expand and in the near future we will see Barcelona city and its metropolitan area as a region where the sun will play an important role as an energy source providing the required energy services (with end-use efficient technologies) for living efficiently on the earth.

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