Renewables 2050

A report on the potential of renewable energies in peninsular Spain

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1. Introduction

Greenpeace has commissioned the Technology Research Institute at the Pontificia Comillas University to carry out a technical analysis of the viability of a system of electricity generation in peninsular Spain with the maximum possible contribution of renewable energies. The analysis takes into account the main factors conditioning the availability of resources, environmental restrictions and other types of land use, the link between demand and generating potential and the transport capacity of the electricity network. The results will be presented in successive reports under the general name "Energy Revolution".

This document shows the main results of the report "Renewables 2050. A report on the potential for renewable energies in peninsular Spain", the first in this project which is carrying out the most detailed published analysis to date in this country of development scenarios for the different renewable technologies. The report provides ceilings for the potential and generation of these technologies, clearly showing the different restrictions both in terms of availability of energy resources and land use.

As a methodology, population and energy demand scenarios were first drawn up for peninsular Spain, based on those already published by other institutions. Based on these and on comparisons with actual and forecast development for each of the renewable technologies, an analysis is made of what their position and activity could be in 2050. Finally, the maximum possible contribution of each of these is developed in terms of power capacity and electricity generation, imposing environmental, social and technological criteria on the type of land available.

Secondly, at a European level, Greenpeace has also carried out specific analyses. In this area, the German institute DLR has established a scenario for Greenpeace International published with the title "Energy Revolution: a sustainable pathway to a clean energy future for Europe". This scenario demonstrates that the restructuring of the energy system to meet ambitious environmental targets is viable, and marks out a transition to replacing conventional energies with renewable ones, so the latter could then provide half the energy mix by the middle of the century.

Why this project?

Our energy system is at a crossroads. The massive consumption of fossil fuels, which are our main energy source, is causing climate change which is already making itself felt. If we continue along this road it is highly probable that we will exceed Nature's limits, which could make it impossible for the majority of species to adapt themselves to such a strong, rapid change, while millions of people will suffer the conditions of an uninhabitable environment in the form of famines, floods, drought…

Meanwhile, governments and energy companies continue to make decisions on multi-million dollar developments without taking this reality into account, prolonging an unsustainable energy model for decades. There is even the continual emergence of smokescreens (the misnamed "clean" coal, construction of new nuclear power stations or extension of the life of the current ones, the myth of the future fusion reactor, hydrogen obtained with dirty energies, carbon sinks, capture and storage of CO_2, etc.), presenting false solutions to climate change while they conceal other serious environmental effects and take up massive financial resources which are vital for the real solutions.

The only real solution to climate change lies in the complete replacement of fossil fuels by renewable energies, together with the more efficient use of energy. However, each time this approach is presented, basic questions come up: are renewables sufficient to cover society's demand for energy? Do we need to develop other energy sources to cover the supposed limitations of renewables?

The answers to these questions will condition a whole series of crucial political and economic decisions that are going to be taken in the next few months and years in this country and in the area of the European Union and which are going to have a decisive influence on humanity's capacity to prevent dangerous climate change:

· The next renewable energies directive, which has to set targets for the contribution of these energies to the energy mix for each EU country with the horizon 2020.
· The National Allocation Plan for emissions for the period 2008-2012, which will determine this country's willingness to meet the Kyoto Protocol Commitment.
· The international negotiations beginning at the first meeting of the Kyoto Protocol signatory countries held in Montreal after the end of November 2005, to set new emission reduction targets beyond 2012, which will have to be much tougher than the current ones established at Kyoto.
· The review of energy planning promised by the Spanish Prime Minister, which must establish the energy demand it is planned to supply over the coming years, the energy infrastructures that will therefore be necessary and whether these will continue to be based on the massive construction of fossil fuel power stations or on an acceleration of investment in renewables.
· The nuclear debate, which must clarify how the Government is going to keep its promise to abandon nuclear energy and stand up to the pressure from big companies which are trying to lengthen the useful lives of the old nuclear power stations.
· Reform of the electricity sector, taking into account the White Paper's proposals to guide it towards sustainability.
· The role consumers could play in being able to choose clean electricity.

The aim of this project is to find out whether renewable energies are enough to meet society's demand for energy or whether, by contrast, we need to develop other energy sources to cover the supposed limitations of renewables. Ultimately, it is a matter of trying to confirm whether it is possible to find the solution to climate change through the complete replacement of fossil fuels by renewable energies together with a more efficient use of energy.

2. Hypothesis and methodology

The study starts from the following **hypotheses:**

- *Spanish peninsular population in 2050:* 38.32 million inhabitants, essentially divided in the same proportions as in 2003.
- *Demand for electrical energy:* 20kWh/inhabitant/day, which gives a peninsular electricity demand of 280TWh/year in 2050. This quantity is obtained by extrapolating from conservative EU scenarios, deducting a certain quantity from final usage demand for energies that are renewable at origin (80% of electricity demand for hot water thanks to the use of solar thermal and biomass boilers; 80% of electric space heating demand thanks to the use of bioclimatic architecture, solar thermal energy, biomass boilers and better insulation in buildings; 60% of demand for electrical space refrigeration thanks to the use of solar thermal energy with absorption machines and bioclimatic techniques), but without including savings due to demand-side management.
- Same division in 2050 as in 2003 of the proportion of electricity demand per head in each autonomous community with respect to the average for Spain.
- Same electricity demand per head in all provinces of the same autonomous community.
- Modulation by time of day of demand for electricity on the peninsula in 2050 the same as in 2003, without taking into account improvements which could be achieved through demand-side management to facilitate the penetration of renewable technologies.
- *Final energy demand:* 109kWh/inhabitant/day, resulting in 1,525TWh/year.

Specific hypotheses have also been taken for each technology.

Concerning the **methodology** followed, it is a matter of determining the capacity and generation ceilings for each technology, with these understood as the power that can technically be developed with the technology considering the resources available and imposing the relevant technical limits for the development of the resource.

The units used to express the capacity ceilings are gigawatts (GW, equivalent to a thousand megawatts or a billion watts), while generation ceilings are expressed in terawatt-hours (TWh, equivalents to a billion kilowatt-hours). The reason for using such "large" and not very common units is that they make it easier to express the very high quantities for ceilings which are obtained as a result.

To calculate the capacity ceilings, we have developed designs for the different technologies, assessed their actions in different geographical regions and imposed technological and land availability restrictions using a GIS (Geographical Information System) tool. The estimates for the generation ceilings have been obtained based on the capacity ceilings using capacity factors evaluated for the different sites considered.

To assess the availability of land for each renewable technology according to land use, the Ministry of Public Works database has been used, which classified all land into:

· Urban zones.
· Industrial, commercial and transport zones.
· Mineral extraction, dumping and construction zones.
· Artificial, non-agricultural green zones.
· Employment land.
· Permanent crops.
· Pasture.
· Heterogeneous agricultural zones.
· Woodland.
· Areas of shrub and herbaceous vegetation.
· Open spaces with little or no vegetation.
· Inland wetland.
· Coastal wetland.
· Inland waterways
· Sea

For each group of land and its subgroups, its possible viability for the installation of each renewable technology considered, or the percentage that could be used in each case, has been assigned.

Environmental restrictions, excluding the use of 28% of land on the peninsula, have also been incorporated (in some autonomous communities this is as much as 40% of their territory). In general, the excluded areas are as follows;

· Nature 2000 Network: Special Protection area for birds (SPAS) and Sites of Community Interest (SCIs).
· Zones associated with Protected Natural Areas (ENP), either declared or in the formal process of being declared by the Spanish government and the Autonomous Communities.

The map shows us all the areas whose use has been excluded for environmental reasons.

Map 1 All the areas excluded for the capacity and generation ceilings for environmental reasons (SCI+SPAS+ENP).
Source: Environment Ministry

3. The main results of the study

3.1. Results by technologies

We are now going to present the main results of the study. Firstly, we will see separately for each technology considered how much of the resource is available in absolute terms, divided by autonomous community, and in comparison with projected electricity demand for 2050.

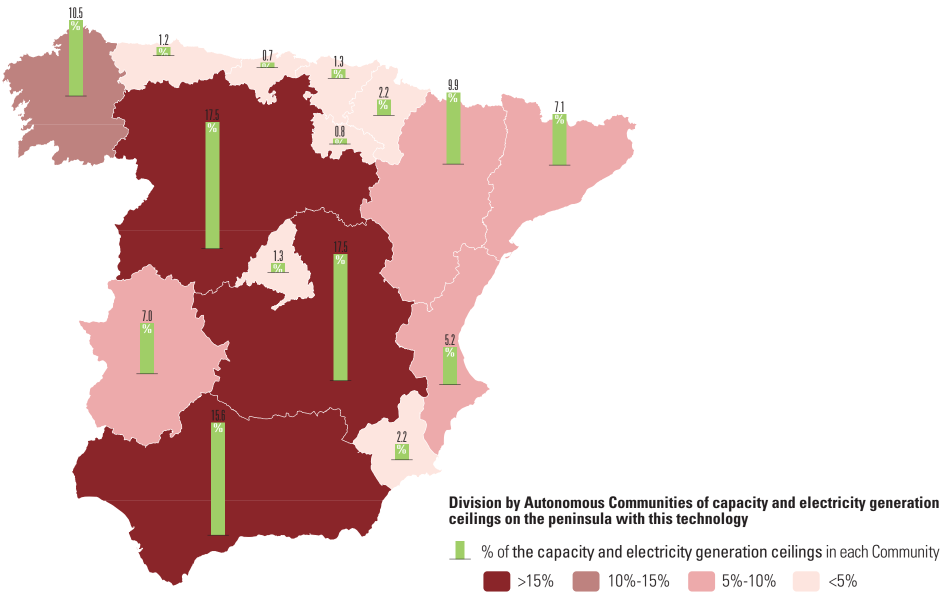
In general, a conservative approach has been adopted; that is, the best technology currently available for converting each renewable resource into electricity has been considered, including technological improvements only when it appears clear that they will be available for 2050.

Geothermal energy is the energy in the subsoil, which is hotter the deeper you go.

The technology considered is hot dry rock technology, for which it is not necessary to have aquifers. Instead, fluid is injected under pressure so that the rocks crack at the desired depth, the fluid receives the heat from the rocks and transports it to the surface, where this heat is converted into electricity, as in a conventional thermal power station.

We have assumed that the operating fluid used would be n-pentane, with rocks at a temperature of 180ºC and efficiency of 11%.

Geothermal. % of the power and electricity generation ceilings in each Community.



Total. Capacity ceiling = 2.48 GW - Electricity generation ceiling = 19.53TWh/y (7% of peninsular electricity demand 2050)

2,480MW of electrical power could be installed based on geothermal energy and 19.53TW/h a year could be generated, which would make it possible to cover 7% of the peninsular electricity demand projected for 2050. As this is an energy that is permanently available, its contribution could be very useful in regulating the electricity system and could also be used for non-electrical purposes. As we can see on the map, the greatest potential is in the two Castiles and Andalusia.

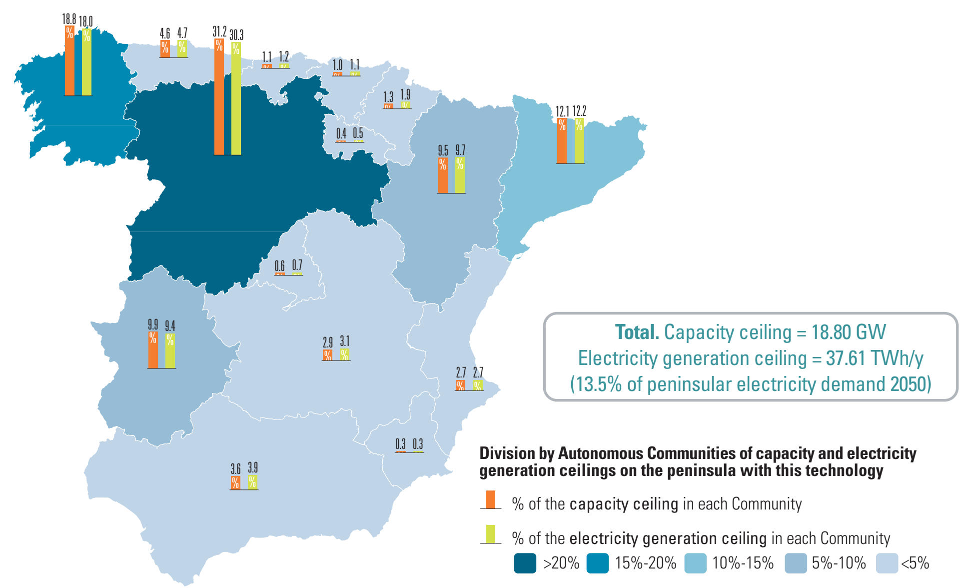
2

Hydro-electric

Hydro-electric energy is that from waterfalls and has traditionally been generated using a turbine.

For this study we have not considered great increases in big-scale hydro-electric power because of the environmental impact of dams. The achievable potential has therefore been considered as the same target adopted in the Renewable Energies Promotion Plan. In order to calculate the electricity that can be produced, a slightly dry year (inter-annual reserves not used) or dry year (reserves used) have been considered.

Hydro-electric. Capacity and electrical generation ceiling with this technology and distribution by Autonomous Communities.



Hydro-electric capacity could reach 18,800MW, which could generate 37.61TWh a year, which would make it possible to cover 13.5% of projected peninsular electricity demand in 2050. As it is storable energy, its contribution could continue to be very useful for regulating the electricity system. As we see on the map, the greatest potential is in Castile-Leon.

This hydro-electric potential has been analysed, differentiating between small-scale hydro-electric (installations with capacity less than 10MW) and power stations of more than 10MW:

- Hydro-electric capacity from small-scale plants could reach 2,280MW, which could generate 6.91TWh a year, which would make it possible to cover 2.5% of projected peninsular electricity demand for 2050. The greatest potential is in Castile-Leon, Catalonia and Aragon.
- Hydro-electric capacity from installations larger than 10MW could reach 16,571MW, which could generate 30.71TWh a year, making it possible to cover 11% of projected peninsular electricity demand for 2050. The greatest potential is in Castile-Leon.

Biomass is the energy from organic material, resulting from waste (forestry, agricultural, stock-rearing, from the agri-food industry or urban waste, converted into biogas) or from energy crops. The study has also assessed the potential of fast-turnover forest crops and scrub.

The technology considered is a high-performance gas turbine power station using as fuel the gas resulting from the gasification of biomass, whatever its origin. The total energy efficiency of the conversion of biomass into electricity would be 32.95%.

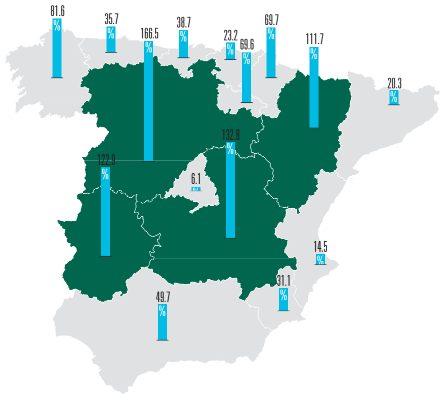
With this system, the waste hot water from the power station could be used for cogeneration applications designed to cover low-temperature demand, such as sanitary hot water, space-heating and cooling using absorption equipment.

Biomass. Capacity and electrical generation ceiling with this technology, distribution by Autonomous Community and percentage of electricity demand that would be covered in 2050.

Division by Autonomous Community of capacity and electricity generation ceilings on the peninsula with this technology

% of the **capacity and electrical generation ceilings** in each Community

>20% 10%-20% 5%-10% <5%



% of electricity demand in 2050 that would be covered with this technology

% of **demand** for each Community

Communities self-sufficient with this technology for their 2050 electricity demand

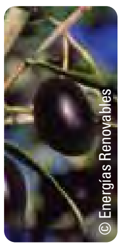
Total. Capacity ceiling = 19.46 GW - Electricity generation ceiling = 141.47 TWh/y (50.5% of 2050 peninsular electricity demand)

19,460MW of electrical power could be installed based on biomass and 141.47TWh a year could be generated, making it possible to cover 50.5% of projected peninsular electricity demand for 2050. As it is an energy that can be stored, its contribution could be very useful for regulating the electricity system as well as being available for non-electrical uses. As we see on the map, the greatest potential is in Castile-Leon. It should be highlighted that Castile-Leon, Castile-La Mancha, Extremadura and Aragon could use biomass to generate a quantity of electricity greater than their own projected electricity demand for 2050.

This biomass potential has been analysed by making two different calculations, admitting land with different gradients. The results shown on the map correspond to a maximum gradient of 10%. If the maximum admissible gradient is restricted to 3% for forest crops and 4% for scrub, it would still be possible to install 15,200MW, which would generate 109.8TWh/year, equivalent to 39.2% of peninsular electricity demand in 2050.

The biomass results broken down by applications are;

- *Scrub:* 2,310MW, 17.2TWh/y (6.1% of 2050 peninsular demand) on a gradient of up to 10%. Greatest potential in Galicia and Castile-Leon.
- *Fast turnover forest crops:* 5,130MW, 38.2TWh/year (13.6% of 2050 peninsular demand) on a gradient of up to 10%. Greatest potential in Castile-Leon and Galicia.
- *Energy crops:* 4,735MW, 35.22TWh/year (12.6% of 2050 electricity demand). Greatest potential in Castile-Leon.
- *Waste and biogas:* 7,280MW, 50.85TWh/y (18.2% of 2050 electricity demand). Greatest potential in Andalusia.



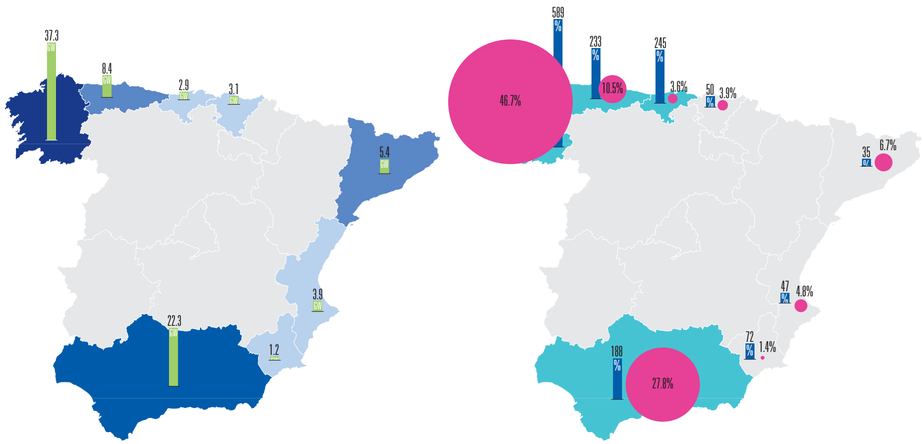
4

Waves

The mechanical energy from waves can be used to be converted into electricity, although this is not yet at a commercial stage in this country. However, given the peninsula's long coastline, we thought it was worth assessing its potential. Because of the lack of data, this is done approximately.

We have considered that only 90% of the available potential could be used along a strip between 5 and 30km from the coast in a line running parallel to it, overlapping the systems so there was no continuous barrier. Part of the infrastructures would be shared with those for off-shore wind power, as both could coexist on the same site.

Waves. Capacity and electricity generation potential with this technology, distribution by Autonomous Communities and percentage of electricity demand that would be covered in 2050.



Division by Autonomous Community of capacity and electricity generation ceilings on the peninsula with this technology

Average annual **capacity** (GW) in each Community

>30% 20%-30% 5%-20% <5%

% of 2050 electricity demand that would be covered with this technology

% of **demand** in each Community

% of peninsular **demand**

Communities self-sufficient in this technology for their 2050 electricity demand

Total. Capacity ceiling = 84.4 GW - Electricity generation ceiling = 296 TWh/y (105.7% of 2050 peninsular electricity demand)

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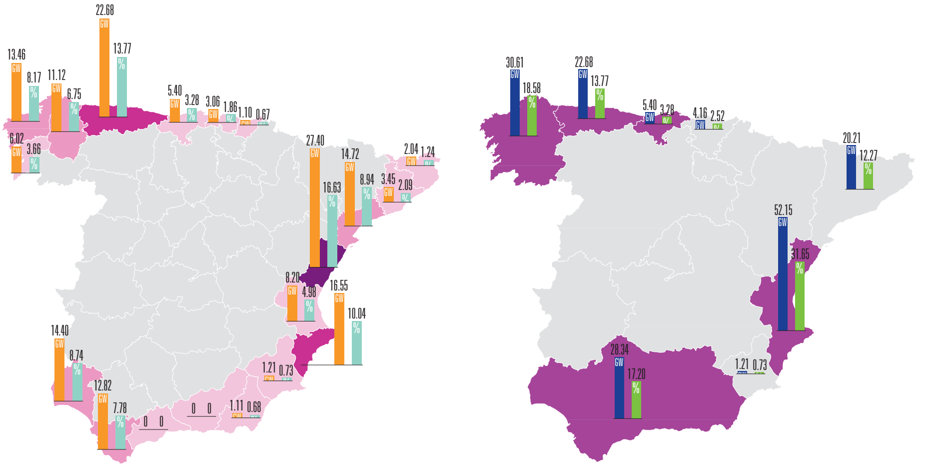
84,400MW of electrical power could be installed, based on wave energy, and 296TWh a year could be generated, making it possible to cover 105.7% of projected peninsular electricity demand in 2050. As we can see on the map, the greatest potential is in Galicia.

Off-shore wind energy turns the strength of the wind into electricity using wind-generators sited at sea.

The technology considered is that of a wind-generator operating at variable rotation speed, with individual change of pitch for each blade. The chosen machine would generate 4.5MW and is 114m in diameter, with a hub height of 120m. A power capacity density of 5.6MW/km² is considered, at a distance of between 5 and 40km from the coast and depth of up to 100m.

Off-shore wind. Capacity ceiling (in GW) and electrical generation (in % of the total) with this technology, and distribution by provinces and by Autonomous Communities.



Division by provinces of capacity ceilings and electricity generation on the peninsula with this technology

- **Capacity ceiling** in each province (GW)
- % of the **electricity generation ceiling** in each province
- >15% 10%-15% 5%-10% <5%

Division by Autonomous Communities of capacity ceilings and electricity generation on the peninsula with this technology

- **Capacity ceiling** in each Community (GW)
- % of the **electricity generation capacity ceiling** in each Community
- Communities self-sufficient with this technology for their 2050 electricity demand

Total. Capacity ceiling = 164.76 GW - Electricity generation ceiling = 334 TWh/y (119.3% of 2005 peninsular electricity demand)

164,760MW of electrical capacity could be installed based on off-shore wind energy and 334TWh a year could be generated, which would cover 119.3% of projected peninsular demand in 2050. As we can see on the map, the greatest potential is in Castellón. It should be highlighted that Galicia, Asturias, Cantabria, Valencia and Andalusia could generate a quantity of electricity greater than their own projected electricity demand with off-shore wind power in 2050.

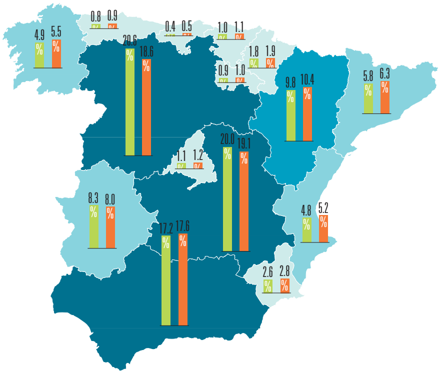
6

On-shore wind

On-shore wind energy turns the strength of the wind into electricity using wind-generators based on land. We analyse two types of land depending on the relief: flat and uneven.

The technology considered is that of a three-blade direct transmission wind-generator (without speed multiplication), with operation at reduced speed and individualised pitch for each blade and low start-up speeds (2-2.5m/s). The chosen machines would generate, respectively, 2.05MW (71m in diameter and hub height of 80m) on flat land and 810kW (48m in diameter and boss height of 65m) on uneven land, in wind farms with 15 wind-generators, so the farm size would be 30.75MW on flat land and 12.15MW on uneven land. A density of power capacity of 3.84MW/km² is considered on flat land and 3.04MW/km² on uneven land.

On-shore wind. Capacity and electricity generation ceiling with this technology, distribution by Autonomous Community and percentage of electricity demand that would be covered in 2050.



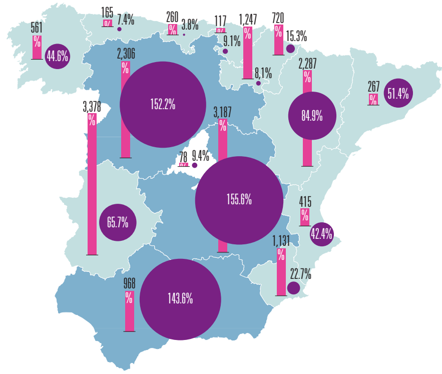
Division by Autonomous Community of capacity and electricity generation ceilings on the peninsula with this technology

% of the **capacity ceiling** in each Community

% of the **electricity generation ceiling** in each community

>15% 10%-15% 5%-10% <5%

Total. Capacity ceiling = 915 GW
Electricity generation ceiling = 2,285 TWh/y
(816.1% of 2050 peninsular electricity demand)



% of electricity demand that would be covered with this technology in 2050

% of **peninsular demand**

% of **demand** in each Community

Communities self-sufficient with this technology for their 2050 electricity demand

Communities that could generate all peninsular electricity demand with this technology

915,000MW of electrical power based on on-shore wind energy could be installed and 2,285TW/h a year could be generated, which would make it possible to cover more than eight times the projected peninsular electricity demand in 2050. As we see on the map, the greatest potential is in the two Castiles and Andalusia. It should be highlighted that each of these could generate a quantity of electricity greater than the total projected peninsular electricity demand in 2050. In addition, all communities, with the only exception of Madrid, could generate a quantity of electricity greater than their own projected electricity demand with on-shore wind energy in 2050.

This on-shore wind energy potential has been analysed by making two different calculations, with two different methods. The results shown on the map correspond to the most reliable method[1], which results in greater potential. With the other approach[2], 1,902TWh/year would be generated, equivalent to 679% of peninsular electricity demand in 2050.

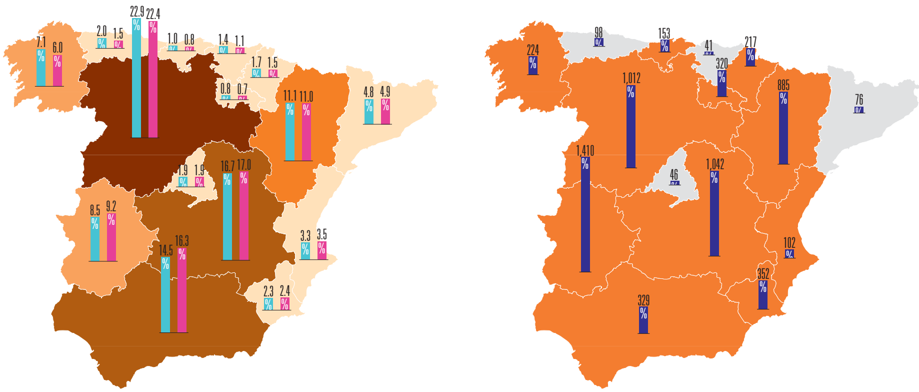
[1] Consistent with assuming that the average sites associated with flat and uneven land throughout the peninsula are properly represented by just two Weibull distributions.
[2] Consistent with adopting the values for the overall capacity factors recorded in 2003 by the Autonomous Communities.

A solar chimney power station consists of a large, flat solar collector which, like a greenhouse, turns all the solar radiation into heat energy. A very tall chimney is placed in the middle of the collector, taking the hot air up by natural convection, activating a turbine positioned inside the chimney to generate electricity. It operates 24 hours a day thanks to energy storage in the ground and the protection from losses provided by the collector.

The technology considered would require a minimum of four km^2 per power station, with an installed power density of $4.5MW/km^2$.

We consider sites with a gradient of 2% with any orientation and up to 7% with orientation from SE to SW.

Solar chimney. Capacity and electricity generation ceiling with this technology, distribution by Autonomous Community and percentage of electricity demand that would be covered in 2050.



Division by Autonomous Community of capacity and electricity generation ceilings in the on the peninsula with this technology

% of the **capacity ceiling** in each Community

% of the **electricity generation ceiling** in each Community

>20% 15%-20% 10%-15% 5%-10% <5%

% of electricity demand in 2050 which would be covered by this technology

% of **demand** in each Community

Communities self-sufficient with this technology for their 2050 electricity demand

Total. Capacity ceiling = 324.3 GW - Electricity generation ceiling = 836.2 TWh/y
(298.6% of 2050 peninsular electricity demand)

324,300MW of electrical capacity could be installed based on solar chimneys and 836.2TWh a year could be generated, which could cover around three times projected peninsular electricity demand in 2050. As we see on the map, the greatest potential is in the two Castiles and Andalusia. It should be highlighted that Galicia, Cantabria, La Rioja, Navarre, Aragon, Valencia, Murcia, Castile-La Mancha, Castile-Leon, Extremadura and Andalusia could generate a quantity of electricity greater than their own projected electricity demand with solar chimneys in 2050.

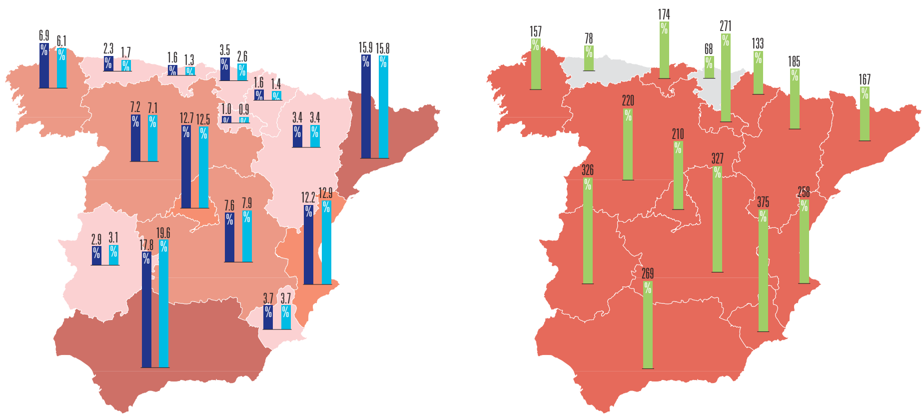
8

Solar photovoltaic integrated into buildings

Solar photovoltaic energy turns the light we receive from the sun directly into electricity, thanks to the photoelectric effect of the silicon making up the photovoltaic modules. They are connected to the electricity grid via an inverter, which transforms the direct current from the module into electricity with the same characteristics as that of the grid.

The technology considered is that of a photovoltaic module whose average performance throughout its useful life (40 years with the horizon of 2050) coincides with that of a modern high-performance module. We have considered two types of system: those integrated into buildings and solar photovoltaic energy with tracking. With the applications integrated into buildings, the maximum proximity between generation and consumption (distributed generation) is achieved, as well as avoiding competition for land use with any other technology or use. We will consider different usage factors depending on whether the modules are positioned on the roof or on façades with different orientations (S, SE, SW, E, W).

Solar photovoltaic integrated into buildings. Capacity and electricity generation ceiling with this technology, distribution by Autonomous community and percentage of electricity demand that would be covered in 2050.



Division by Autonomous Communities of capacity and electricity generation ceilings on the peninsula with this technology

% of the **capacity ceiling** in each Community

% of the **electricity generation ceiling** in each Community

>15% 10%-15% 5%-10% <5%

% of electricity demand that would be covered with this technology in 2050

% of the **demand** of each Community

Communities self-sufficient with this technology for their 2050 electricity demand

Total. Capacity ceiling = 494.5 GWp - Electricity generation ceiling = 569.3 TWh/y
(203% of 2050 peninsular electricity demand)

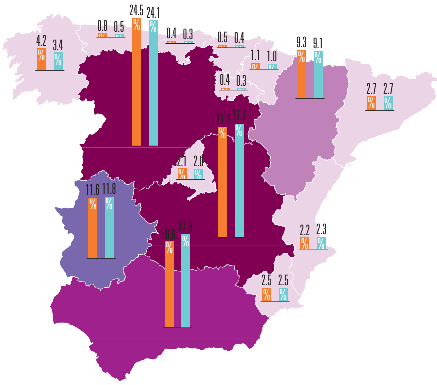
494,500MWp of photovoltaic capacity integrated into buildings could be installed and 569.3TWh a year could be generated, which would make it possible to cover more than twice projected peninsular electricity demand in 2050. As we can see on the map, the greatest potential is in Andalusia and Catalonia. It should be highlighted that all Communities, except Asturias and the Basque Country, could generate a quantity of electricity greater than their own projected electricity demand with solar photovoltaic energy integrated into buildings in 2050.

Solar photovoltaic energy with tracking is achieved with groups of photovoltaic generators that have a mechanism making it possible to track the "movement" of the sun from east to west, achieving better performance. These are an interesting alternative for people or organisations lacking the space to integrate a photovoltaic installation into their building but who still want to invest in solar photovoltaic energy to generate clean energy.

The land occupation and power densities will depend on the latitude, making sure that at the end of January there are no shadows in the SE and SW directions.

We consider land with a gradient of less than 3% with any orientation and up to 10% with SE to SW orientations.

Solar photovoltaic with tracking. Capacity and electricity generation ceiling with this technology, distribution by Autonomous Communities and percentage of electricity demand that would be covered in 2050.

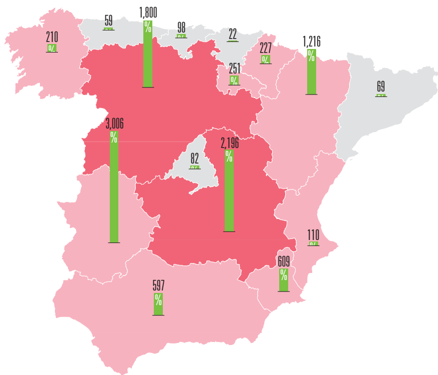


Division by Autonomous Communities of capacity and electricity generation ceilings on the peninsula with this technology

% of the **capacity ceiling** in each Community

% of the **electricity generation ceiling** in each Community

>20% 15%-20% 10%-15% 5%-10% <5%



% of electricity demand that would be covered by this technology in 2050

% of **demand** in each Community

Communities self-sufficient in this technology for their 2050 electricity demand

Communities that could generate the entire peninsular electricity demand with this technology

Total. Capacity ceiling = 708.4 GWp - Electricity generation ceiling = 1,382.2 TWh/y
(494% of 2050 peninsular electricity demand)

708,400MWp of photovoltaic capacity could be achieved in solar photovoltaic energy installations with tracking and 1,382.2TWh a year could be generated, which would make it possible to cover around five times projected peninsular electricity demand in 2050. As we can see on the map, the greatest potential is in the two Castiles. It should be highlighted that both of these autonomous communities could generate a quantity of solar photovoltaic energy with tracking greater than the entire projected peninsular electricity demand in 2050. In addition, Extremadura, Aragon, Murcia, Andalusia, La Rioja, Navarre, Galicia and Valencia could generate a quantity of energy greater than their own projected electricity demand with this technology in 2050.

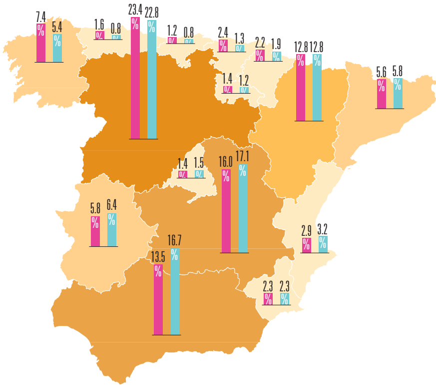
10

Concentrated solar thermal

A concentrated solar thermal power station uses a field of mirrors to concentrate direct solar radiation, heating a fluid to high temperatures. Electricity is generated with this hot source as in a conventional thermal power station.

The technology chosen for this analysis, which is supposed to represent all concentrated solar thermal technologies, is that of a power station of parabolic trough-shaped minor reflectors with a N-S orientation, using water as the working fluid, with dry cooling (so that the availability of water is not a restriction) using aero-condensers and with a storage tank with capacity for 15 hours, making it possible to have abundant, stable generation potential.

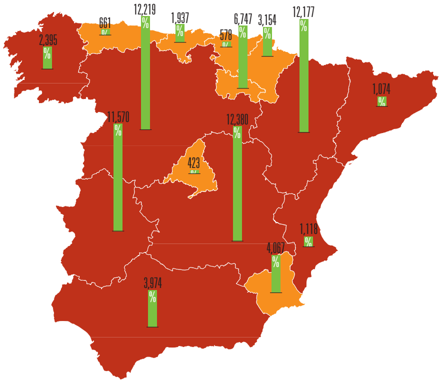
Concentrated solar thermal. Capacity and electrical generation ceiling with this technology, distribution by Autonomous Communities and percentage of electricity demand that would be covered in 2050.



Division by Autonomous Community of capacity and electricity generation ceilings on the peninsula with this technology

- % of the **capacity ceiling** in each Community
- % of **electricity generation** in each Community

>20% | 15%-20% | 10%-15% | 5%-10% | <5%



% of electricity demand that would be covered by this technology in 2050

- % of **demand** in each Community
- Communities self-sufficient for their 2050 electricity demand with this technology
- Communities that could generate the entire peninsular electricity demand with this technology

Total. Capacity ceiling = 2,739 GW - Electricity generation ceiling = 9,897 TWh/y (3,534% of 2050 peninsular electricity demand)

2,739,000MW of electrical capacity could be available in solar thermal power stations and 9,897TWh a year could be generated, making it possible to cover more than thirty-five times projected peninsular electricity demand in 2050. As we can see on the map, the greatest potential is in Castile-Leon.

It should be highlighted that both this Community and Castile-La Mancha, Andalusia, Aragon, Extremadura, Catalonia, Galicia and Valencia could each generate a quantity of electricity greater than the entire projected peninsular electricity demand with solar thermal power stations in 2050. In addition, all the peninsular Communities could generate a quantity of electricity greater than their own projected electricity demand with solar thermal power stations in 2050.

3.2. Synthesis of results

Total renewable resources available

The following graphs show the peninsular capacity and generation ceilings for the different technologies considered in this project, together with the percentages of coverage of projected peninsular electricity and total energy demand for 2050.

The great generation potential of renewable energies as a whole should be highlighted, with some of them alone achieving a generation ceiling greater, and in some cases much greater than projected demand for 2050, both for electricity (280TWh/year) and for total energy (1,525TWh/year).

If we add all the ceilings for the different technologies, we will obtain a maximum total generation ceiling based on renewables of 15,798TWh/year. The intersections to be deducted because of coinciding sites would be very low, because in most cases they are compatible or because very restrictive prior conditions have been imposed on the available land. This generation ceiling with renewables represents a generation potential equivalent to more than fifty-six times peninsular

Graph 1 Generation ceiling with renewables

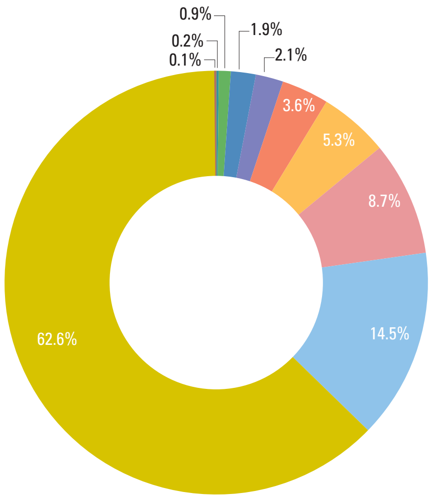
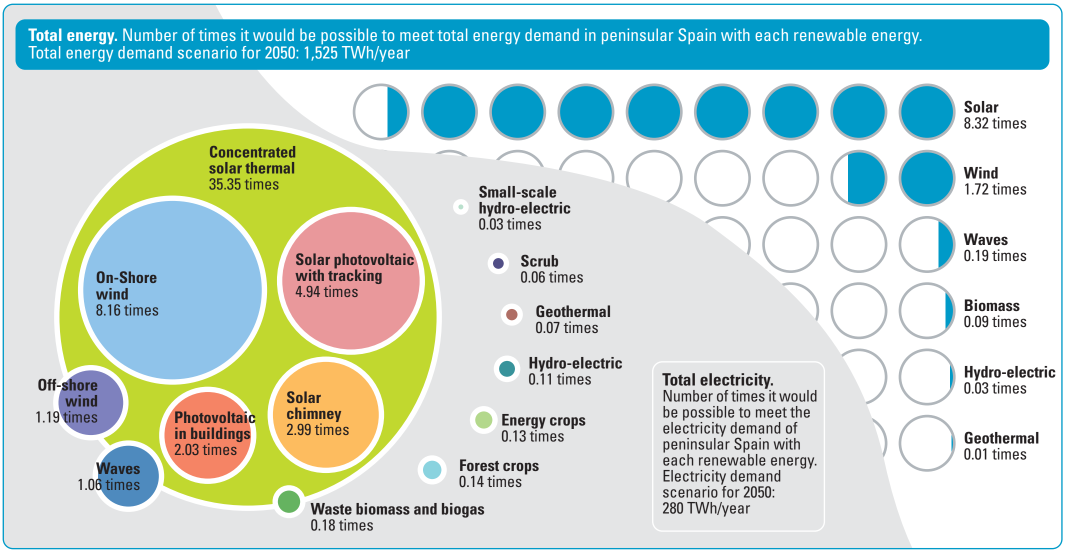


Table 1 Renewable resources available in Spain and comparison with demand in 2050

	Capacity Ceiling GWp	Generation Ceiling TW.h/year	Electricity demand (%)	Total energy demand (%)
Solar	4,266	12,684	4,530	832
Concentrated solar thermal	2,739	9,897	3,535	649
Solar photovoltaic with tracking	708	1,382	494	91
Solar chimney	324	836	299	55
Integrated photovoltaic	495	569	203	37
Wind	1,080	2,619	935	172
On-shore wind*	915	2,285	816	150
Off-shore wind	165	334	119	22
Waves	84	296	106	19
Biomass	19	142	51	9
Waste biomass and biogas	7	51	18	3
Energy crops	5	35	13	2
Fast turnover forest crops*	5	38	14	3
Scrub	2	17	6	1
Hydro-electric	19	38	14	3
Hydro-electric (P> 10MW)	17	31	11	2
Small-scale hydro-electric (P< 10MW)	2	7	3	0.5
Hot dry rock geothermal	3	20	7	1
Total renewables	5,471	15,798	5,642	1,036

* The maximum generation ceilings are shown



electricity demand for 2050 and more than ten times total peninsular energy demand for 2050.

As we can see in the diagram, the most abundant renewable resources by far are those associated with **solar** technologies. The great potential of concentrated solar thermal energy, which could meet more than thirty-five times projected **electricity demand for** 2050, should be highlighted. Other solar technologies could also generate several times the electricity demand for 2050: solar photovoltaic with tracking (about five times demand), solar chimney (about three times demand) and photovoltaic integrated into buildings (twice demand). The high generation ceiling for **wind** power is also worth highlighting: with off-shore wind alone it would be possible to meet the entire projected electricity demand in 2050 and eight times as much with on-shore wind power. Wave energy would also be enough to the entire peninsular electricity demand. The potential of other renewable technologies could meet significant percentages of electricity demand: waste biomass and biogas (18%), forest crops (14%), energy crops (13%), hydro-electric (11%), geothermal (7%), scrub (6%) and small-scale hydro-electric (3%).

If we look at **the entire projected peninsular energy demand** in 2050 (1525TWh/year), with solar technology it would be possible to meet around eight times this demand, and with wind up to 1.72 times this demand could be met.

Comparison with the Renewable Energies Plan

The capacity and generation ceilings obtained in this project are a long way, both in terms of quantity and quality from the envisaged for planning

Table 2 Comparison between the capacity ceiling calculated for 2050 and the target for capacity in the Renewable Energies Plan for Spain 2005-2010

	Target capacity (MW) for 2010 in the REP	Capacity ceiling (MW) 2050 Escenario 2050
Concentrated solar thermal	500	2,738,800
Solar photovoltaic	400	1,202,900
Wind	20,155	1,079,900
Solar chimney	0	324,300
Waves	0	84,400
Total biomass (including biogas)	2,274	19,400
Hydro-electric	18,977	18,800
Hot dry rock geothermal	0	2,500
Solid Urban Waste	189	0*
Total	**42,495**	**5,471,000**

*Greenpeace does not consider the incineration of solid urban waste as renewable energy.

the development of renewable technologies in this country.

If we compare the targets in the Renewable Energies Plan 2005-2010 (REP) set by the Spanish government for 2010 and the ceiling obtained in this project, we will see that, in terms of quantity, the latter are several orders of magnitude higher.

The first thing that attracts the attention is the clear contrast between the potential contribution that **solar** technologies could have and the target set in the REP. Among these technologies, the outstanding one is concentrated solar thermal energy, with a capacity ceiling five thousand times greater than the power capacity target set in the REP for 2010 (500MW). Some of the technologies, like solar chimney, are not even considered, although it would be possible to meet up to three times electricity demand with them in 2050.

On and off-shore **wind** have capacity ceilings much higher than the REP target for 2010. Despite its considerable commitment to wind power, the REP target comes nowhere near exhausting the potential of this technology. The complete absence of off-shore wind power in the REP is also noteworthy.

The Generation potential of technologies not currently included in the REP, such as **wave** energy, which has great synergies with off-shore wind power in its technological development, is also very notable.

Concerning **biomass,** the capacity ceilings obtained, although above those estimated in the REP, are those which have the most similar order of magnitude.

For **Hydro-electric** capacity, the ceilings from the previous Ministry of Works Renewable Energies Plan have been adopted as valid, as this is considered a mature technology, whose potential and restrictions (basically environmental ones) are already well established.

Concerning hot dry rock **geothermal,** it would seem appropriate to incorporate it into the programmes intended to develop renewable energies in this country. Although it has a relatively low potential compared with other technologies, it can make a significant contribution to meeting demand and regulating the generation and electricity transport system.

Although the REP considers energy from **solid urban waste,** in this study it is not considered as an acceptable renewable resource.

Meeting electricity demand: Proposed generation mix

With such a high renewable generation potential, there are infinite options for establishing a 100% renewable generation mix with capacity to meet demand. In **the second part of this project, this analysis will be undertaken in more detail,** taking into account the time link between demand and generation and the transport capacity of the electricity network to achieve a 100% renewable scenario in 2050.

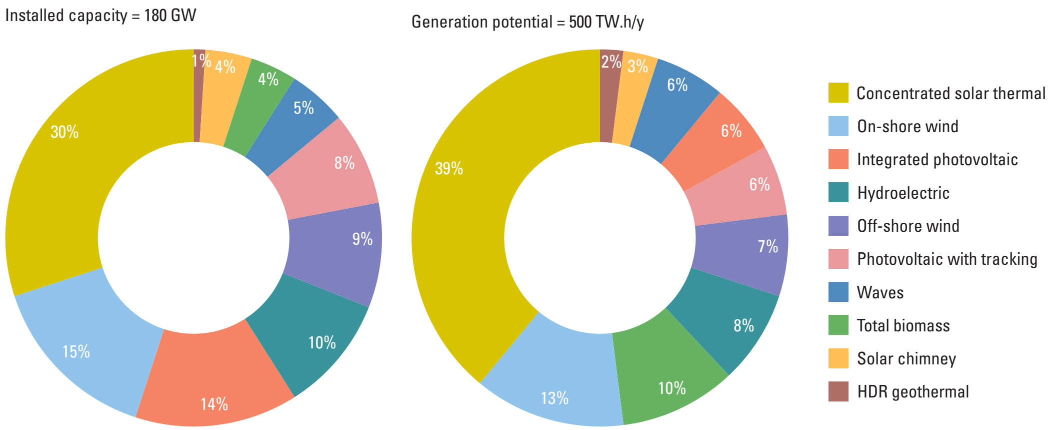
Before that, it would be interesting to have some idea of the configuration required to meet 100% of electricity demand. With the philosophy of technological diversification, the graphics show a possible technological mix with generation potential of 178% of projected electricity demand (this is the over-dimensioning necessary if the electricity grid is used for distributing electricity with 56% regulation-transport efficiency).

Table 3 shows how such a system could be configured with total peak capacity of 180GW, generation potential of 500TWh/year and occupation of 5.3% of the surface of the peninsula. It also details the percentage of each technology's ceiling that needs to be developed in the proposed mix. Due to the great potential of concentrated solar thermal, only 2% of its potential would be developed. Because of its land requirement, only 3% of on-shore wind power would be developed. By contrast, because they are mature

Table 3 and Graphics Preliminary proposal for a mix of technologies to meet 100% of peninsular electricity demand (assuming a regulation and transport system with 56% efficiency). Percentage share of the installed capacity and generation potential of the different technologies

	Capacity GWp	Generation TW.h/year	Potential developed (%)	Occupation of territory (%)
Solar	100	271	2	0.7
Concentrated solar thermal	55	198	2	0.3
Solar photovoltaic with tracking	14	28	2	0.2
Solar chimney	7	17	2	0.3
Integrated photovoltaic	25	29	5	
Wind	44	102	4	1.7
On-shore wind*	28	69	3	1.7
Off-shore wind	17	33	10	
Waves	8	30	10	
Biomass	7	53	37	2.8
Waste biomass and biogas	6	41	80	
Energy crops	1	7	20	1.3
Fast turnover forest crops*	0.4	3	20	0.5
Scrub*	0.3	2	20	1.1
Hydro-electric	19	38	100	
Hydro-electric (P> 10MW)	17	31	100	
Small-scale hydro-electric (P< 10MW)	2	7	100	
Hot dry rock geothermal	1	8	40	
Total renewables	180	500	3	5.3

* Minimum ceilings are shown



technologies with a lower generation ceiling, almost the entire potential of technologies like hydro-electric or waste biomass and biogas would be developed.

The percentage shares of installed capacity and generation potential show us that more than 50% of generating potential corresponds to solar technologies, of which the largest percentage would be concentrated solar thermal, with 39% of generation potential. Wind (on and off based) would provide 19% of generating potential and biomass 10%. The rest would be divided between the various renewable technologies.

Covering total energy demand: proposed mix

The most appropriate technology mix and its spatial division in terms of the geography of the peninsula would be conditioned by the energy distribution system implemented, by the need to regulate generation (closely linked to the demand-side management carried out) and by the development of the cost of each of the technologies considered.

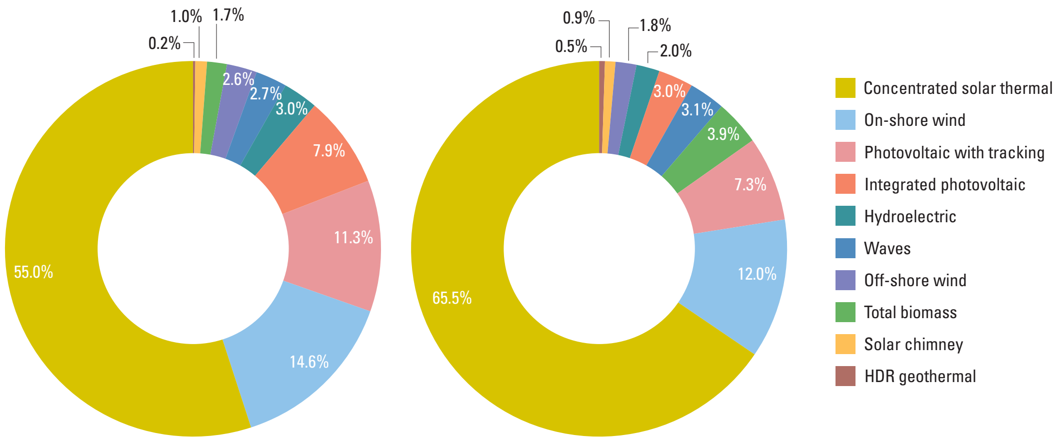
Here we show a preliminary proposal for a technology mix to meet 100% of peninsular energy demand with renewable energies, assuming a regulation and transport system with 80% efficiency.

Table 4 shows how such a system could be configured with total peak power of 627GW, generating potential for 1900TWh/year and occupation of 14.1% of the territory of the peninsula. Details are also given of the proportion of each technology's ceiling required.

The percentage share of capacity and generating potential show us that more than 76% of generating potential corresponds to solar technologies, of which the highest percentage corresponds to concentrated solar thermal, with 65.5% of generating potential and 7.3% to solar photovoltaic with tracking.

Table 4 and Graphics Preliminary proposal for a mix of technologies to meet 100% of total peninsular energy demand (assuming a regulation and transport system with 80% efficiency). Percentage share of installed capacity and generation potential for the different technologies.

	Capacity GWp	Generation TW.h/year	Potential developed (%)	Occupation of territory (%)
Solar	471	1,457	11	2.8
Concentrated solar thermal	345	1,245	13	1.7
Solar photovoltaic with tracking	71	138	10	0.9
Solar chimney	7	17	2	0.3
Integrated photovoltaic	50	57	10	
Wind	108	262	10	5.7
On-shore wind	92	229	10	5.7
Off-shore wind	17	33	10	
Waves	17	59	20	
Biomass	11	75	53	5.6
Waste biomass and biogas	7	51	100	
Energy crops	2	14	40	2.5
Fast turnover forest crops	0.8	6	40	0.9
Scrub	0.5	4	40	2.2
Hydro-electric	19	38	100	
Hydro-electric (P> 10MW)	17	31	100	
Small-scale hydro-electric (P< 10MW)	2	7	100	
Hot dry rock geothermal	1	10	50	0.0
Total renewables	627	1,900	12	14.1



Installed capacity = 627 GW

Generation potencial = 1,900 TW.h/y

On-shore wind power would amount to 12% of generating potential. The rest would be split between the various renewable energies.

3.3. Results by Autonomous Community

We will now show the number of times it would be possible to meet the projected demand for electrical and total[3] energy for each autonomous community in 2050.

These results are interesting in order to appreciate the spatial distribution of renewable energy resources in peninsular Spain, as well as serving as a guide to the development of the promotion and support for the different renewable energies in the context of the communities.

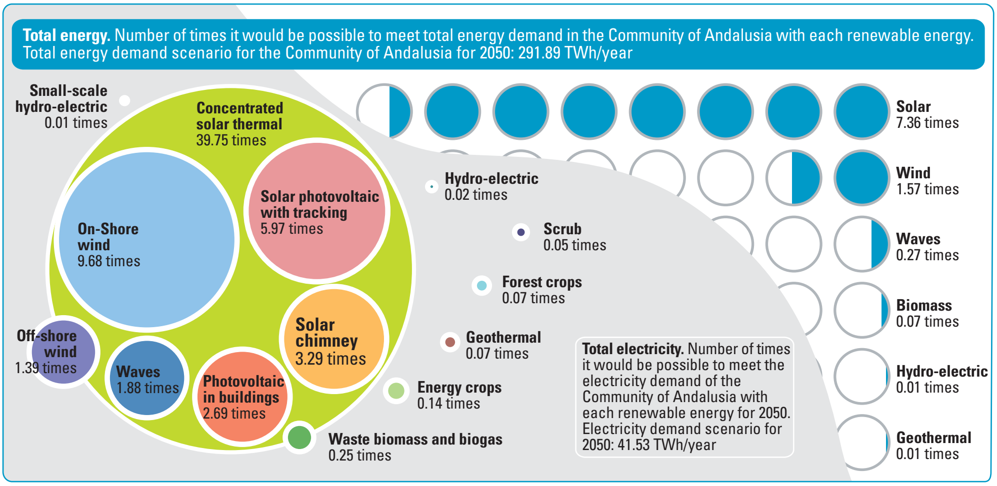
Andalusia

Andalusia is the peninsular Community with the greatest potential for generating electricity from solar photovoltaic energy integrated into buildings and from waste biomass and biogas. It could be self-sufficient for its entire electricity demand with renewable energies, but it could also achieve self-sufficiency with any one of these: solar thermal, photo-voltaic solar with tracking, solar photovoltaic integrated into buildings, solar chimneys, on-shore wind, off-shore wind or wave energy. It could also generate enough with solar thermal or on-shore wind energy to meet the entire peninsular electricity demand.

As we see in the diagram, Andalusia could generate enough **electricity** to meet fifty-two times its demand for electricity by developing all its solar potential.

It could meet almost forty-two times projected demand for Andalusia for 2050 (41.53TWh/year) and six times total peninsular electricity demand (280TWh/year) with concentrated solar thermal power alone. On-shore wind capacity could meet ten times Andalusia's electricity demand. A quantity of electricity greater than the Community's demand could be generated with off-shore wind power. Wave energy could meet almost double Andalusia's electricity demand.

This Community's solar potential would make it possible to meet seven times the projected **total energy demand** for this Community for 2050 (291.89TWh/year) and wind capacity would meet almost twice the demand.



Total energy. Number of times it would be possible to meet total energy demand in the Community of Andalusia with each renewable energy. Total energy demand scenario for the Community of Andalusia for 2050: 291.89 TWh/year

[3] Maximum generation ceilings have been used for on-shore wind, power fast turnover forest crops and the use of scrub.

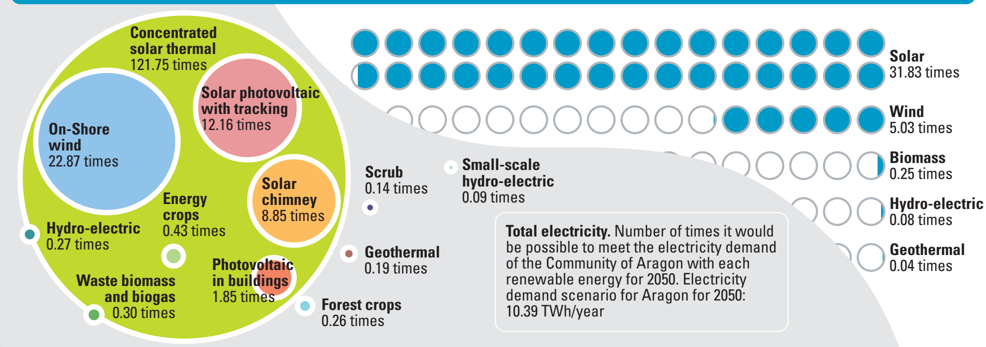
Aragon

Aragon could be self-sufficient for its entire electricity demand with renewable energies and could even achieve this with any one of the following: solar thermal, solar photovoltaic with tracking, solar photovoltaic integrated into buildings, solar chimneys, on-shore wind or biomass. It could also generate enough with solar thermal energy to meet the entire peninsular electricity demand.

As we see in the diagram, Aragon could generate enough **electricity** to meet one hundred and forty-five times its electricity demand with only the solar potential it has. The great potential of concentrated solar thermal power, which could meet almost one hundred and twenty-two times the projected electricity demand for the community in 2050 (10.39TWh/year) and five times the total peninsular electricity demand (280TWh/year), should be highlighted. With other solar technologies, such as solar photovoltaic with tracking, solar chimney and photovoltaic integrated into buildings, it could also generate several times this Community's electricity demand for 2050. With on-shore wind power, Aragon could generate up to twenty-three times its own projected electricity demand in 2050.

This Community's solar potential would make it possible to meet thirty-two times the projected **total energy demand** for this Community in 2050 (47.2TWh/year) and its wind potential would generate 5 times demand.

Total energy. Number of times it would be possible to meet total energy demand in the Community of Aragon with each renewable energy. Total energy demand scenario for the Community of Aragon for 2050: 47.2 TWh/year



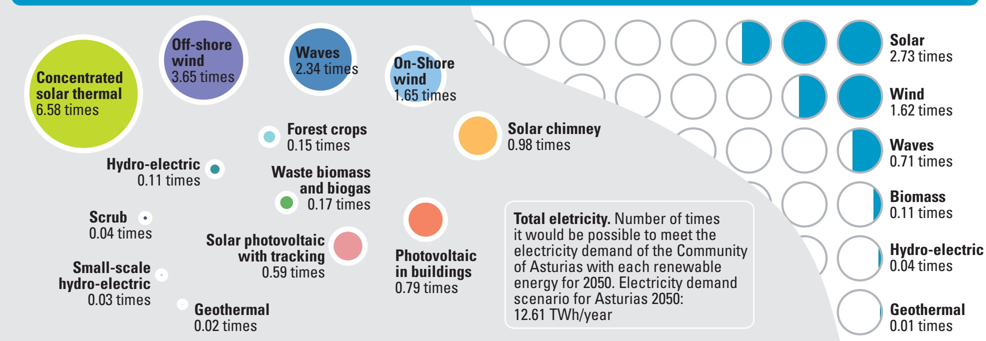
Asturias

Asturias could be self-sufficient for its entire electricity demand with renewable energies and it could even achieve this with any one of the following: solar thermal, on-shore wind, off-shore wind or wave energy.

As we can see in the diagram, Asturias could generate enough **electricity** to meet almost seven times its projected electricity demand in 2050 (12.61TWh/year, by developing its entire concentrated solar thermal potential. Wind power could more than five times Asturias' electricity demand. With Off-shore wind power almost four times as much electricity could be generated as the demand from the Community. Wave energy could meet more than twice its electricity demand.

This Community's solar potential would make it possible to meet three times the projected **total energy demand** for this community for 2050 (41.26TWh/year) and its wind potential would meet twice the total demand.

Total energy. Number of times it would be possible to meet total energy demand in the Community of Asturias with each renewable energy. Total energy demand scenario for the Community of Asturias for 2050: 41.26 TWh/year

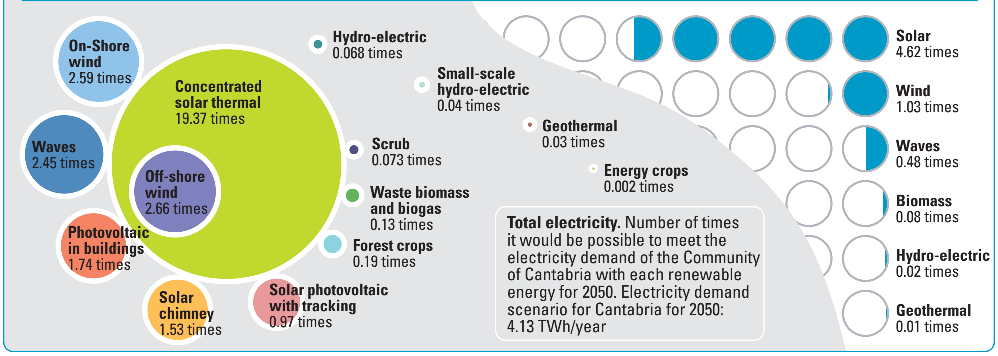


Cantabria

Cantabria could be self-sufficient for its entire electricity demand with renewable energies and it could even achieve this with any of the following: solar thermal, solar photovoltaic integrated into buildings, solar chimneys, on-shore wind, off-shore wind or wave energy.

As we can see in the diagram, Cantabria could generate enough **electricity** to meet twenty-four times its electricity demand by developing all its solar potential. With concentrated solar thermal power alone it could meet nineteen times the projected electricity demand for this community for 2050 (4.13TWh/year). With other solar technologies, such as solar chimney and photovoltaic integrated into buildings, it could also generate several times this community's electricity demand for 2050. On-shore wind power could meet 2.59 times Cantabria's electricity demand. Almost three times the Community's demand for electricity could be generated with off-shore wind power. Wave energy could more than twice meet its electricity demand. This Community's wind potential would enable it to meet the entire projected **total energy demand** for this Community for 2050 (21.09TWh/year) and its solar potential would achieve five times the demand.

Total energy. Number of times it would be possible to meet total energy demand in the Community of Cantabria with each renewable energy. Total energy demand scenario for the Community of Cantabria for 2050: 21.09 TWh/year

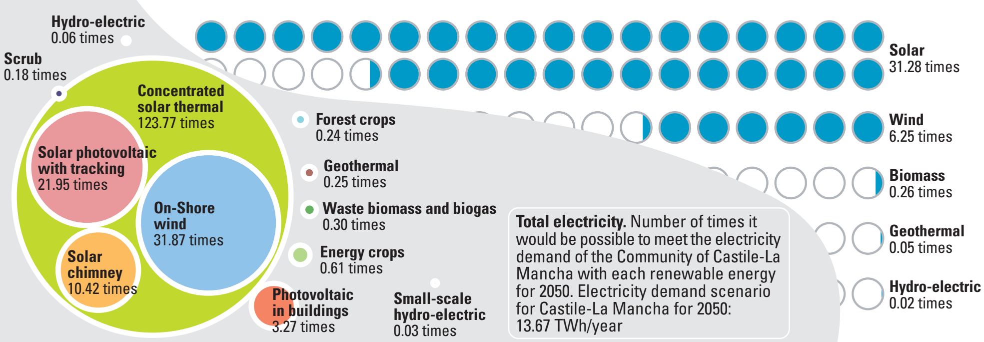


Castile-La Mancha

Castile-La Mancha is the Community on the peninsula with the greatest potential for generating electricity from geothermal energy (together with Castile-Leon) and from on-shore wind energy. As we can see in the diagram, Castile-La Mancha could be self-sufficient in renewable energies for its entire projected **electricity** demand for 2050 (13.67TWh/year) and it could even achieve this with just one of the following: solar thermal (one hundred and twenty-four times over), solar photovoltaic with tracking (twenty-two times over), solar photovoltaic integrated into buildings, solar chimneys, on-shore wind (almost thirty-two times over) or biomass.

With solar thermal energy (six times over), solar photovoltaic with tracking or on-shore wind power it could also generate enough energy to meet the whole peninsula's electricity demand. This Community's solar potential could meet thirty-one times the projected **total energy demand** for this Community for 2050 (69.67TWh/year) and its wind potential could achieve this six times over.

Total energy. Number of times it would be possible to meet total energy demand in the Community of Castile-La Mancha with each renewable energy. Total energy demand scenario for the Community of Castile-La Mancha 2050: 69.67 TWh/year

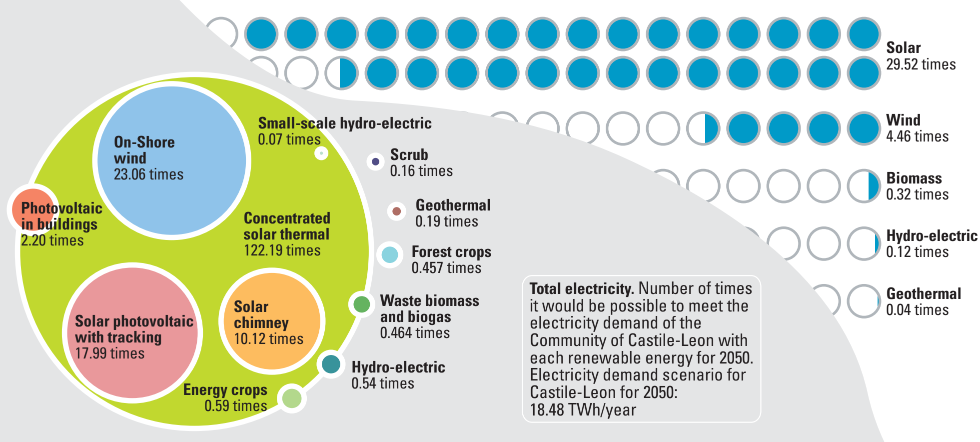


Castile-Leon

Castile-Leon is the peninsular Community with greatest potential for generating electricity from geothermal energy (together with Castile-La Mancha), hydro-electric, biomass, solar chimneys, solar photovoltaic with tracking and solar thermal energy.
As we can see in the diagram, Castile-Leon could be self-sufficient in renewable energies for its entire projected **electricity** demand for 2050 (18.48TWh/year), and it could even achieve this with just one of the following: solar thermal (more than one hundred and twenty two times over), solar photovoltaic with tracking (eighteen times over), solar photovoltaic integrated into buildings, solar chimneys, on-shore wind (twenty-three times over) or biomass. It could also generate enough energy to meet the peninsula's entire electricity demand with solar thermal energy (eight times over), photovoltaic with tracking or on-shore wind (twice over).

This Community's solar potential would enable it to meet thirty times the projected **total energy demand** for this Community for 2050 (95.46TWh/year) and its wind power would achieve this figure four times over.

Total energy. Number of times it would be possible to meet total energy demand in the Community of Castile-Leon with each renewable energy. Total energy demand scenario for the Community of Castile-Leon for 2050: 95.46 TWh/year

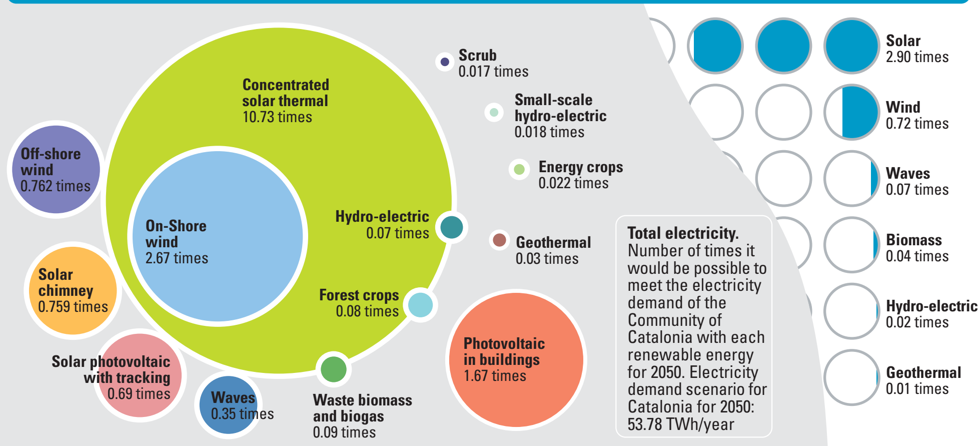


Catalonia

As we can see in the diagram, Catalonia could be self-sufficient with renewable energies for its entire projected **electricity** demand for 2050 (53.78TWh/year), and it could even achieve this with only one of the following: solar thermal (eleven times over), solar photovoltaic integrated into buildings (twice over), or on-shore wind (almost three times over). It could also generate enough with solar thermal energy to meet twice the peninsula's electricity demand.

This Community's solar potential would make it possible to meet three times the projected **total energy demand** for this Community for 2050 (257.25TWh/year).

Total energy. Number of times it would be possible to meet total energy demand in the Community of Catalonia with each renewable energy. Total energy demand scenario for the Community of Catalonia for 2050: 257.25 TWh/year

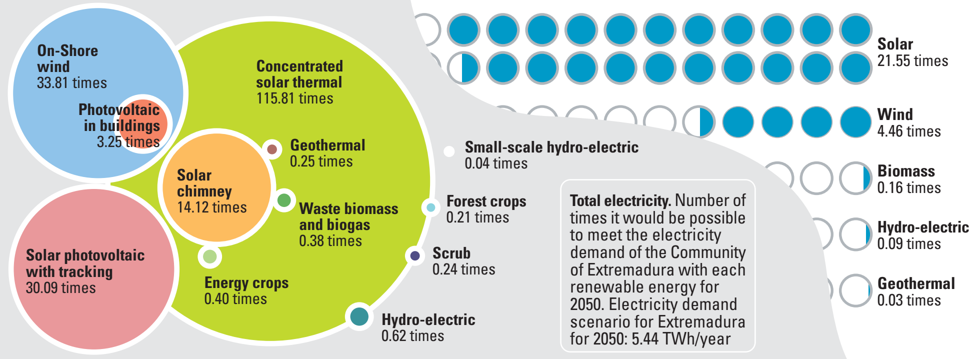


Extremadura

As we can see in the diagram, Extremadura could be self-sufficient in renewable energies for its entire projected **electricity** demand for 2050 (5.44TWh/year), and it could even achieve this with just one of the following: solar thermal (almost one hundred and sixteen times over), solar photovoltaic with tracking, photovoltaic integrated into buildings, solar chimneys, on-shore wind (thirty-four times over) or biomass.
Extremadura could generate enough electricity to meet one hundred and sixty-three times its projected electricity demand in 2050 by developing all the solar potential it has. It could also generate enough with solar thermal energy to meet double the peninsula's electricity demand.

This Community's solar potential makes it possible to meet almost twenty-two times the projected **total energy demand** for this Community for 2050 (41.21TWh/year) and its wind potential would achieve more than four times demand.

Total energy. Number of times it would be possible to meet total energy demand in Extremadura with each renewable energy.
Total energy demand scenario for Extremadura for 2050: 41.21 TWh/year



Galicia

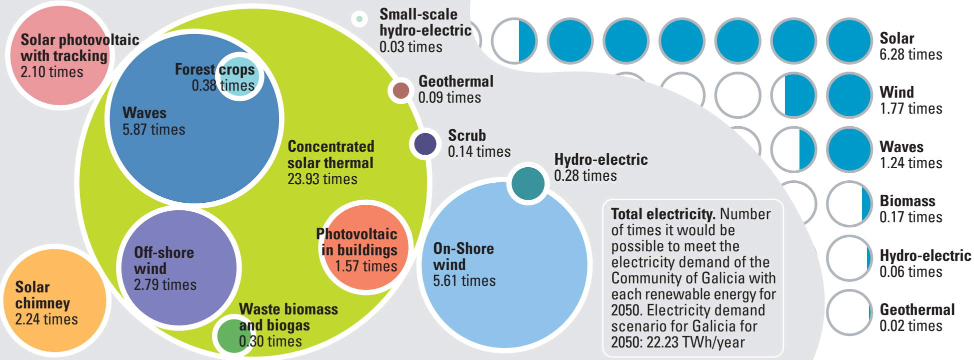
Galicia is the peninsular community with the greatest potential for generating electricity from scrub biomass and from wave energy.

As we can see in the diagram, Galicia could be self-sufficient in renewable energies for its entire projected **electricity** demand for 2050 (22.23TWh/year), and it could even achieve this with just one of the following: solar thermal (almost twenty-four times over), photovoltaic with tracking, photovoltaic integrated into buildings, solar chimneys, on-shore wind (three times over) or wave energy (almost six times over).

Galicia could generate enough electricity to meet thirty times its projected electricity demand for 2050 by developing all its solar potential and nine times demand by developing its wind potential. It could also generate enough with solar thermal energy to meet double the peninsula's electricity demand.

This Community's solar potential would make it possible to meet six times the projected **total energy demand** for this Community for 2050 (105.56TWh/year). Its wind potential could achieve twice the demand and demand could also be met by wave power.

Total energy. Number of times it would be possible to meet total energy demand in the Community of Galicia with each renewable energy.
Total energy demand scenario for 2050: 105.56 TWh/year

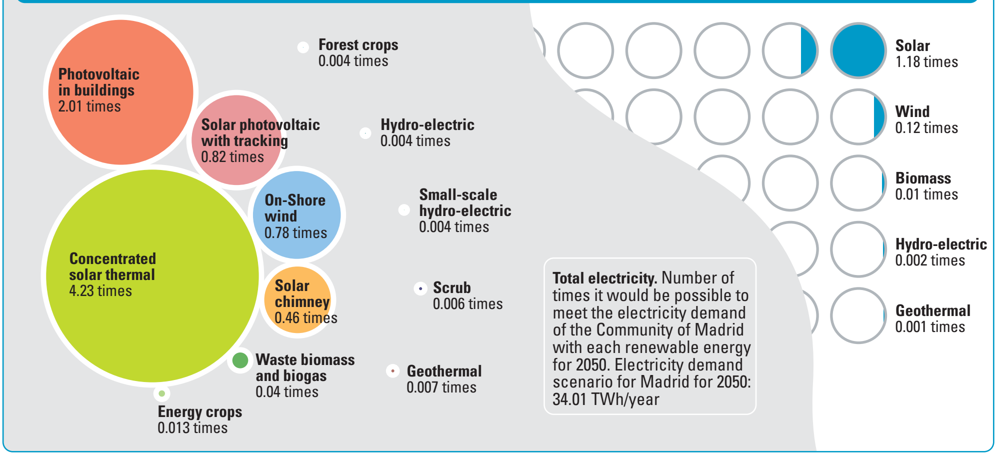


Madrid

As we can see in the diagram, the Community of Madrid could be self-sufficient in renewable energies for its entire projected **electricity** demand for 2050 (34.01TWh/year), and it could even achieve this only with solar thermal energy (more than four times over) or with photo-voltaic integrated into buildings (twice over). The Community of Madrid could generate enough energy to meet seven times its projected electricity demand in 2050 by developing its full solar potential.

It would be possible to meet the projected **total energy demand** for the Community of Madrid for the year 2050 (219.45TWh/year) by developing its entire solar potential.

Total energy. Number of times it would be possible to meet total energy demand in the Community of Madrid with each renewable energy. Total energy demand scenario for the Community of Madrid for 2050: 219.45 TWh/year

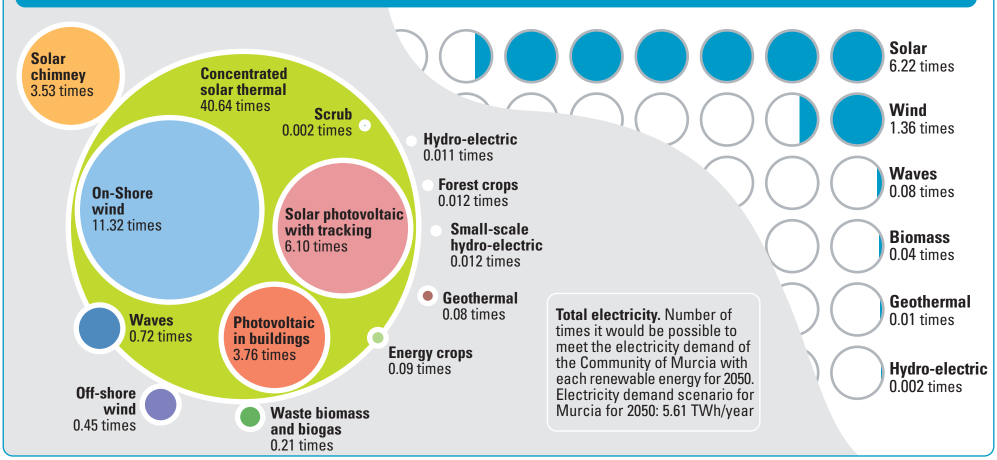


Murcia

As we can see in the diagram, the Region of Murcia could be self-sufficient in renewable energies for its entire projected **electricity** demand for 2050 (5.61TWh/year), and it could even achieve this with just one of the following: solar thermal (forty-one times over), solar photovoltaic with tracking, solar photovoltaic integrated into buildings, solar chimneys or on-shore wind (more than eleven times over). The Region of Murcia could generate enough electricity to meet fifty-five times its projected electricity demand in 2050 by developing all its solar potential.

It would be possible to meet the projected **total energy demand** for the Region of Murcia for the year 2050 (48.7TWh/year) by developing its entire wind power potential and to achieve this six times over by developing its full solar potential.

Total energy. Number of times it would be possible to meet total energy demand in the Community of Murcia with each renewable energy. Total energy demand scenario for the Community of Murcia for 2050: 48.7 TWh/year

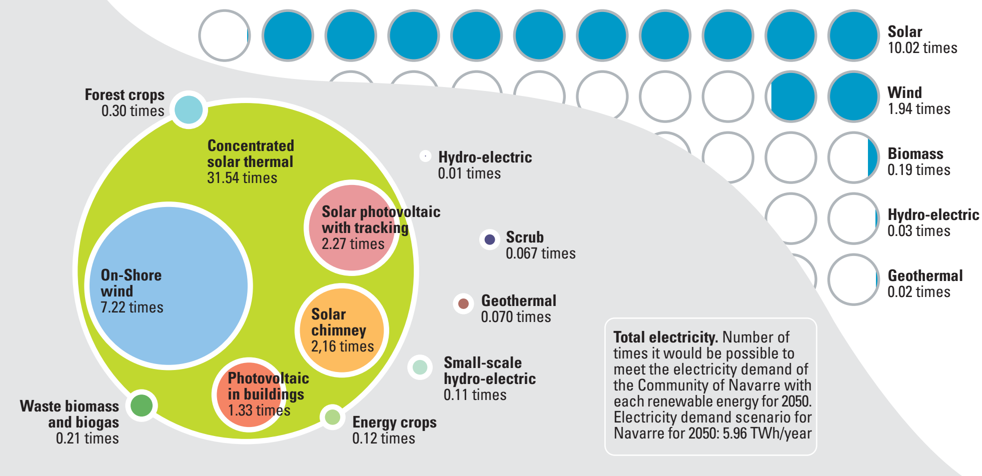


Navarre

As we see in the diagram, the Autonomous Community of Navarre could be self-sufficient in renewable energies for its entire projected **electricity** demand for 2050 (5.96TWh/year), and it could even achieve this with any one of the following: (solar thermal (almost thirty-two times over), solar photovoltaic with tracking, solar photovoltaic integrated into buildings, solar chimneys or on-shore wind power (more than seven times over). Navarre could generate enough electricity to meet thirty-six times its projected electricity demand in 2050 by developing its full solar potential.

It would be possible to meet ten times the projected **total energy demand** for the Autonomous Community of Navarre for 2050 (22.19TWh/year) by developing its full solar potential and to do so almost twice over by developing all its wind power potential.

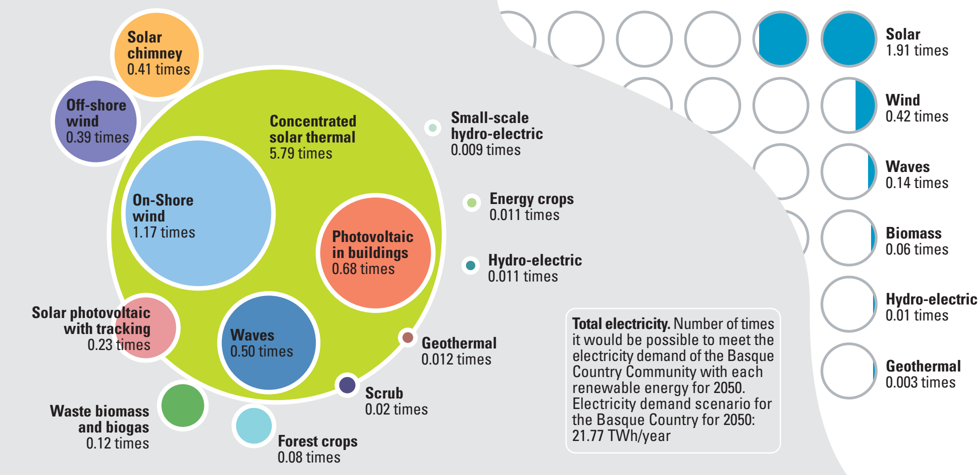
Total energy. Number of times it would be possible to meet total energy demand in the Community of Navarre with each renewable energy. Total energy demand scenario for the Community of Navarre for 2050: 22.19 TWh/year



Basque Country

As we can see in the diagram, the Basque Autonomous Community could be self-sufficient with renewable energies for its entire projected **electricity** demand for 2050 (21.77TWh/year) and it could even achieve this just with solar thermal energy (almost six times over) or with on-shore wind. It would be possible to meet almost twice the projected **total energy demand** for the Basque country for 2050 (81.05TWh/year) by developing its full solar potential.

Total energy. Number of times it would be possible to meet total energy demand in the Basque Country Community with each renewable energy. Total energy demand scenario for the Basque Country Community for 2050: 81.05 TWh/year

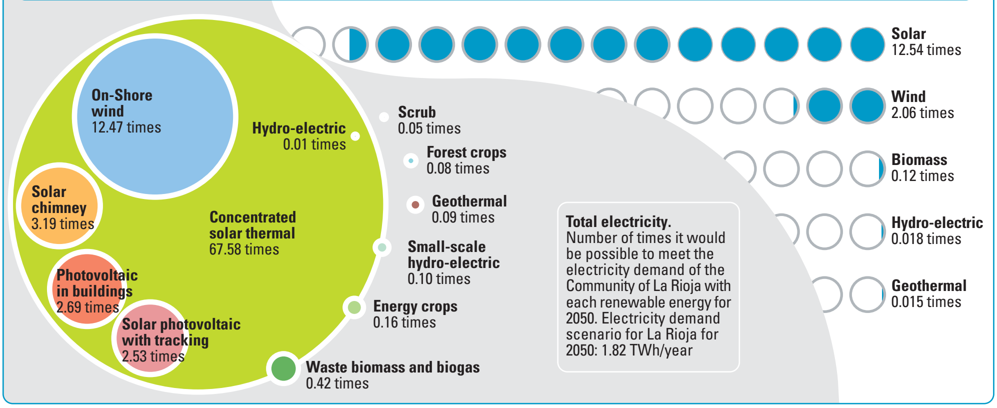


La Rioja

As we can see in the diagram, La Rioja could be self-sufficient with renewable energies for its entire projected **electricity** demand for 2050 (1.82TWh/year), and it could even achieve this with any one of the following: solar thermal (sixty-eight times over), solar photovoltaic with tracking, solar photovoltaic integrated into buildings, solar chimneys or on-shore wind power (twelve times over). La Rioja could generate enough electricity to meet seventy-seven times its projected electricity demand for 2050 by developing its entire solar potential.

It would be possible to meet almost thirteen times the projected **total energy demand** for La Rioja for 2050 (11.03TWh/year) by developing its full solar potential and to achieve twice the demand by developing its wind potential.

Total energy. Number of times it would be possible to meet total energy demand in the Community of La Rioja with each renewable energy.
Total energy demand scenario for the Community of La Rioja for 2050: 11.03 TWh/year



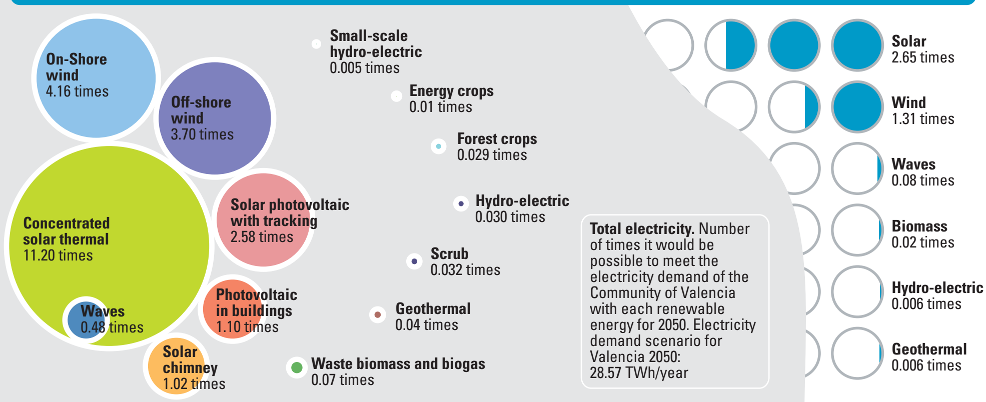
Valencian Community

The Valencian Community is the peninsular Community with the greatest potential for generating electricity from off-shore wind energy.

As we can see in the diagram, the Valencian Community could be self-sufficient with renewable energies for its entire projected **electricity** demand for 2050 (28.57TWh/year), and it can even achieve this just with any one of the following: solar thermal (more than eleven times over), solar photovoltaic integrated into buildings (up to three times over), solar chimneys, on-shore wind power or off-shore wind power (four times over). The Valencian Community could generate enough electricity to meet sixteen times its projected electricity demand in 2050 by developing the full potential offered by solar energy. This Community could meet its electricity demand eight times over by developing all its wind energy potential. It could also generate enough energy with solar thermal power to meet the peninsula's entire electricity demand.

It would be possible to meet the entire projected **total energy demand** for the Valencian Community for 2050 (171.56TWh/year) by developing all its wind potential and meet this demand almost three times over by developing its solar potential.

Total energy. Number of times it would be possible to meet total energy demand in the Community of Valencia with each renewable energy.
Total energy demand scenario for the Community of Valencia for 2050: 171.56 TWh/year



4. Conclusions of the report and Greenpeace's demands

Conclusions

· The **electricity generating potential with renewable sources** is much greater than demand. If we add the ceilings obtained for each of the technologies, we would reach a maximum of 15,798TWh/year, equivalent to **56.42 times projected peninsular demand for electricity** in 2050.

· Having such a high renewable generating potential makes it possible for us to suggest the theoretical possibility of meeting all energy demands, not just for electricity, because it is equivalent to **10.36 times projected total peninsular energy demand** for 2050.

· **The most abundant renewable resources are those associated with solar energy:** with all solar technologies, energy equivalent to 8.32 times the peninsula's total energy demand in 2050, with concentrated solar thermal energy, whose generation potential is 62.6% of total renewable the most important. This means our most important energy reserve is the sun, confirming that we really are in "the land of the sun", something which contrasts with the absolutely marginal role given up to now in energy planning to the different ways of making use of solar energy.

· **The potential for wind energy is much greater than current planning targets.** To obtain land occupation with on-shore wind energy similar to other technologies it would not be necessary to develop more than a tenth of its potential in order to install more than four times the power currently planned.

· There are technologies which until now have been virtually ignored in the planning and regulation of incentives, such as off-shore wind energy, wave energy, dry rock geothermal energy or solar chimneys, which show a great potential for generating energy.

· **Biomass** resources are limited in relation to other renewables. Because of this, and as its great regulation capacity could play an important role in the current electricity system, **maximum efficiency must be prioritised when using it,** in combined heat and power applications (co-generation), without detriment to its necessary contribution in sectors such as transport and the heating/air conditioning of buildings. There are sufficient resources for the entire co-generation capacity currently planned to be able to operate with biomass.

· **There are an infinite number of options for configuring a 100% renewable electricity generation mix.** Although the second part of this project will develop this in depth, advance mention can be made of a possible set of generating facilities, over-dimensioned to 178% and 180,000MW of installed capacity, combining the different renewable technologies, that would be able to generate the full projected demand for electricity in 2050, occupying 5.3% of the territory.

· **It would be technically viable to supply 100% of total energy demand with renewable sources.** The most appropriate combination of technologies and their geographical location would depend on the energy distribution system, on the need to regulate generation (linked to demand-side management) and the development of the cost of each technology.

· Renewable resources are **so widely distributed in the territory of the peninsula** that all autonomous communities have enough capacity to fully meet their own electricity and total energy demands.

What Greenpeace is asking for

To prevent dangerous climate change and the other environmental effects of dirty energies, and given the abundance of renewable resources available, as well as taking into account the great investment absorbed by the energy system and the long period it takes to get a return on this, it is urgent to establish coherent strategies for developing our energy system towards a 100% renewable horizon. In order to drive forward this Energy Revolution, the following are requirements:

· The establishment of compulsory legal targets as part of the next **European Renewable Energy Directive** so that renewable energies supply at least 20% of primary energy demand in each of the 25 EU states for 2020, indicating a specific target for each renewable energy, in accordance with each country's renewable resources.
· A stronger system of **renewable energy premiums,** guaranteeing investors a stable and attractive return on investment for each technology.
· The development of a **green tax system,** including tax breaks and rebates for investment in renewable energies, especially for solar energy.
· A guarantee that renewable energies will have **priority access to the grid.**
· Giving priority to the development of solar technology in Spain, setting more ambitious targets in accordance with its enormous potential, making it possible to create strong markets for each application of **solar energy** in order to turn Spain into the "country of solar energy". Urgent approval for the compulsory use of thermal and photovoltaic energy in buildings that built or refurbished.
· The approval of a **off-shore wind energy plan** determining the criteria for the territorial siting of this energy and preventing situations of social lack of understanding.
· The encouragement of the sustainable use of **biomass** imposing strict environmental criteria for the selection of resources and creating distribution grids to facilitate its use and to make it profitable, compelling its use in co-generation wherever technically possible.
· The incorporation into the renewable energies plan of high-potential technologies which until now have been "forgotten": waves, geothermal, solar chimneys.
· The guaranteeing of consumers' rights to **choose clean energy,** limiting the market power of the big utilities and establishing electrical labelling mandating utilities to provide standardised, reliable information on their bills and advertisements about the origin and environmental impact of the energy they are selling.
· The establishment of compulsory **energy efficiency,** targets, including annual energy saving of at least 2.5% for the private sector and 3% for the public sector.
· A review of the current **energy plan,** as promised by the Spanish Prime Minister, setting targets of greater efficiency and lower energy demand and planning the necessary energy infrastructures, not to continue the massive construction of thermal power stations but to accelerate investment in renewables.
· **The elimination of all subsidies on fossil fuels and nuclear energy,** and the internalisation of all their external costs.

· **The disincentivisation of investment in new fossil-fuel power stations,** , making it compulsory to show, by way of a detailed analysis, that all clean energy resources (efficiency and renewables) have been exhausted or are insufficient, before authorising the construction of any fossil fuel power stations.

· The implementation of an **urgent phase-out plan for existing nuclear power stations,** with the horizon of 2015, in accordance with the PSOE's (Spanish Socialist Party) electoral promise and the Governmental manifesto of Prime Minister Rodríguez Zapatero.

· The approval of a **National Emissions Allocation Plan** for the period 2008-2012, ensuring that Spain meets the target it committed itself to in the Kyoto Protocol.

· The negotiation of **new, tougher emission reduction targets** for the second commitment period of the Kyoto Protocol (2013-2017) and tightening them for the third commitment period (2018-2022), with an overall reduction of at least 30%.

Appendix

Glossary of terms

Demand for electrical energy or demand for electricity.
This is the quantity of electricity the population consumes during a time interval, whether consumption is in the domestic, industrial or service sectors or others.
Electricity demand per head is expressed in kWh/inhabitant.
To speak of peninsular electricity demand in this study, we use TWh/year.

Total or final energy demand
This is the quantity of energy (in the form of heat, electricity, movement...) consumed by the population in a given time in all sectors: transport, domestic, industrial, service...

To make it comparable with electricity demand, we use the same units: kWh/inhabitant, TWh/year.

Energy and power
The brightness of a light bulb depends on its power (watts), but the energy it uses depends on the time it is switched on (watt-hours). Similarly, a power station that generates energy will have a power or capacity (kW) and the energy this power station produces will be the result of the instantaneous power multiplied by the time the power station is running (kWh).

- **Units**
  W = watt. This is the standard international unit of power.
  KWh = kilowatt-hour, unit of energy.
  Running a device that has one kW of power for one hour will use a kilowatt-hour of energy.

- **Equivalents**
  1kW (kilowatt) = 1000 watts
  1MW (megawatt) = 1000 kilowatts
  1GW (gigawatt) = 1000MW or a billion watts
  1TW= 1000GW or a billion kilowatts

Generation
Production of electrical energy.

Electricity generation mix
This is the combination of different technologies used to generate the electricity needed to meet electricity demand. It is also known as the generation basket or portfolio.

Peak power
Maximum power that can be generated by a solar photovoltaic power station in standard conditions.

Electrical system
All the equipment necessary to provide the electricity service, that is, to make sure consumers have the electricity they need. It includes both the power stations and the grid transporting the electricity between different areas of the country and the one that distributes it to the consumption points.

Electricity generation system
We are talking about the electricity generating system to refer to the part of the electrical system that includes all the generating units (thermal power stations, wind farms…).

Transport and distribution system or grid
The current system of cables used to transport the electricity from the power stations where it is generated to the points of demand. The electrical energy is transported under high voltage between different areas of the country and distributed under low voltage to the points of consumption.

Generation ceiling
The energy that could be generated with each technology if all its potential was developed.

Capacity ceiling
The capacity possible for each technology if all its potential was installed.

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