100% Renewables

A renewable electricity system for mainland Spain and its economic feasibility.

GREENPEACE www.greenpeace.es
Greenpeace Spain's “Energy Revolution” project

Goal and Methodology

“Renewables 2050” report

“Renewables 100%” report

- Cost analysis
- Example of 100% renewable mix to meet all power demand
- Summary of outcomes
- Conclusion
Questions to answer:

• Is it possible to avoid climate change? Are we on time?

• Is it possible to shift clean for dirty energies? What about a specific country, such as Spain? How much of the energy consumed in Spain could come from renewable sources?

• Would power be available anytime (day and night, winter and summer) and anywhere (country and town, industries and residential and commercial buildings) it is demanded? What happens when the sun is not shining and wind is not blowing?

• How many renewable plants would we need and how should they be operated? Where should they be sited?

• Would a renewable-based system cost more?
Goal:

To quantify and evaluate technically the feasibility of a scenario relying on renewable energies for the power generation system in mainland Spain.
Methodology

1. Analysis of capacity and generation ceilings (Renewables 2050)
2. Cost analysis
3. Temporal analysis
4. Power generation system analysis
“Renewables 2050” report

Renovables 2050
A report on the potential of renewable energies in peninsular Spain
Description of the study:

Power generation system feasibility technical analysis

- in Spain's mainland
- with maximum possible contribution from renewables
- restrictions: resource availability, environment, land uses, demand-generation-transport time coupling
- horizon 2050

Outcomes: “Energy Revolution”

First report: “Renewables 2050” (Capacity and generation ceilings)
Methodology:

- Population and energy demand scenarios 2050
- Renewable technologies: situation and performance in 2050
- Environmental, social and technological restrictions over available geographic areas and kinds of land
  - Land availability (Geographic Information System)
- Maximum contribution from each of them: capacity and generation ceilings
Outcomes by technology: CSP

Total. Capacity ceiling = 2739 GW – Electricity generation ceiling = 9897 Twh/y (3534% of 2050 peninsular electricity demand)
Total energy. Number of times it would be possible to meet total energy demand in peninsular Spain with each renewable energy.

Total energy demand scenario for 2050: 1,525 TWh/year

- **Solar**: 8.32 times
- **Wind**: 1.72 times
- **Waves**: 0.19 times
- **Biomass**: 0.09 times
- **Hydro-electric**: 0.03 times
- **Small-scale hydro-electric**: 0.03 times
- **Geothermal**: 0.07 times
- **Scrub**: 0.06 times
- **Hydro-electric**: 0.11 times
- **Energy crops**: 0.13 times
- **Forest crops**: 0.14 times
- **Waste biomass and biogas**: 0.18 times
- **Solar chimney**: 2.99 times
- **Solar photovoltaic with tracking**: 4.94 times
- **Concentrated solar thermal**: 35.35 times
- **Off-shore wind**: 1.19 times
- **Waves**: 1.06 times
- **On-shore wind**: 8.16 times

Total electricity. Number of times it would be possible to meet the electricity demand of peninsular Spain with each renewable energy. Electricity demand scenario for 2050: 280 TWh/year
“Renewables 2050” report

Conclusions:

Electricity generation potential with renewable sources:
- 56.42 times peninsular electricity demand 2050
- 10.36 times peninsular total energy demand

Most abundant renewable resources are those linked to solar energy

Wind power potential is much bigger than current planning targets

Biomass: maximum efficiency in use must be prioritised

Infinite options exist to make a 100% renewable electricity generation mix

It would be technically feasible to supply 100% of total energy demand with renewable sources
"Renewables 100%" report

Comparison

Part One: lower cost technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>LEC (€/KWh)</th>
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</thead>
<tbody>
<tr>
<td>Eólica terrestre llano -1</td>
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<td>Eólica terrestre accidentado -1</td>
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<tr>
<td>Eólica terrestre llano -2</td>
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<tr>
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<td>Olas -1</td>
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<td>Eólica marina -1</td>
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<td>Termosolar -1</td>
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<td>Eólica terrestre llano -4</td>
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<td>Olas -2</td>
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<td>Eólica marina -3</td>
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<td>Biomasa residuos</td>
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<td>Bombeo hidráulico</td>
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<td>Olas -4</td>
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<td>Eólica marina -5</td>
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<tr>
<td>Termosolar -5</td>
<td>27</td>
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<tr>
<td>Biomasa cultivos (R)</td>
<td>28</td>
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</tbody>
</table>

R- Regados, MB- Aprovechamiento monte bajo, SAP- Secano alta productividad, SH- Secano húmedo, SSA- Secano semi-árido, SA+SAF- Secano árido y sistema agroforestal, CFRR-H- Cultivo forestal de rotación rápida (zona húmeda), CFRR-S- Cultivo forestal de rotación rápida (zona seca)
Part Two: higher cost technologies

- Biomasa_MB (1,850 mm/a)
- Biomasa_cultivos (SAP)
- Biomasa_cultivos (SH)
- Biomasa_cultivos (SSA)
- Biomasa_MB (1,000 mm/a)
- Biomasa_MB (700 mm/a)
- Biomasa_cultivos (SA+SAF)
- Biomasa_CFRR-H
- Minihidráulica
- Biomasa_MB (550 mm/a)
- Biomasa_MB (475 mm/a)
- Biomasa_CFRR-S
- Biomasa_MB (425 mm/a)
- Fotovoltaica seguimiento -1
- Fotovoltaica seguimiento -2
- Olas -5
- Fotovoltaica seguimiento -3
- Fotovoltaica edificación -1
- Fotovoltaica seguimiento -4
- Hidroeléctrica
- Fotovoltaica seguimiento -5
- Fotovoltaica edificación -2
- Fotovoltaica edificación -3
- Ciclo combinado (>350 MW)
- Ciclo combinado (200-350 MW)
- Fotovoltaica edificación -4
- Nuclear (500-1,000 MW)
- Fotovoltaica edificación -5

LEC (€/kW.h)

R- Regadíos, MB- Aprovechamiento monte bajo, SAP- Secano alta productividad, SH- Secano húmedo, SSA- Secano semi-árido.
SA+SAF- Secano árido y sistema agroforestal, CFRR-H- Cultivo forestal de rotación rápida (zona húmeda).
CFRR-S- Cultivo forestal de rotación rápida (zona seca).
### “Renewables 100%” report

#### Example: 100% renewable mix

- **Technology diversity**

#### Installed capacity by technology

<table>
<thead>
<tr>
<th>Technology</th>
<th>Installed Capacity</th>
<th>Available Energy</th>
<th>Annual Electricity Cost (LEC)</th>
<th>Solar-Biomass Hybridization</th>
<th>Land Occupation</th>
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</thead>
<tbody>
<tr>
<td>Termosolar</td>
<td>36,60 GW</td>
<td>366,48 TWh/a</td>
<td>4,51 €/kWh</td>
<td>No</td>
<td>2,47 %</td>
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<tr>
<td>Eólica terrestre</td>
<td>16,57 GW</td>
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<tr>
<td>Hidroeléctrica</td>
<td>6,59 GW</td>
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<tr>
<td>Eólica marina</td>
<td>4,85 GW</td>
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<tr>
<td>Olas</td>
<td>4,13 GW</td>
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<td>Biomasa</td>
<td>3,8 GW</td>
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<td>FV edificios</td>
<td>3,72 GW</td>
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<td>Minihidráulica</td>
<td>0,74 GW</td>
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<td>FV seguimiento</td>
<td>0,74 GW</td>
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<tr>
<td>Geotérmica</td>
<td>0,74 GW</td>
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</tbody>
</table>

#### Technology breakdown

- **Installed capacity**: 102,68 GW
- **Available energy**: 366,48 TWh/a
- **Solar Multiplicity (SM)**: 2.5
- **Accumulation capacity**: 1.5 TWh
- **Meeting demand (SF)**: 100 %
- **Energy shortfall in relation to annual demand**: 0 %
- **Energy to be dissipated in relation to annual demand**: 34.4 %
- **Available generation in relation to annual demand**: 141.6 %
- **Energy contributed by biomass**: 3.8 TWh/a
- **Maximum deficit capacity**: 0 GW
- **Maximum dissipated capacity**: 60.9 GW
Annual hourly evolution of available power, demand, dissipation and deficit for a mix with SM= 2.5 with storage capacity of 1.5 TWh. SF=100%
“Renewables 100%” report

Example 100% renewable mix

Technology diversity
Installed capacity by technology

Configuration and electricity generation, mix optimized for NSEC = 500c€/kWh, SM=2.29, SF=99.993%, LEC= 2.42 c€/kWh
Annual hourly evolution of non-supplied power for an optimized mix for NSEC = 500 c/kWh, SM= 2.29, SF= 99.993%; LEC= 2.42 c€/kWh

Annual hourly evolution of marginal cost of non-supplied electricity for an optimized mix for NSEC = 500 c/kWh, SM= 2.29, SF= 99.993%; LEC= 2.42 c€/kWh
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Summary of outcomes

- Geographic dispersion $\Rightarrow$ generation more regular on time

- **Solutions to fluctuation of available resource**: more installed capacity; regulate with biomass, geothermal, hydro; hybridate solar thermal-biomass (increases security of supply and cuts system cost)

- There are multi-fold renewable mixes able to meet the whole demand

- **Technology diversity** $\Rightarrow$ less necessary capacity and more security of supply

- Minimum need for energy storage
“Renewables 100%” report

Summary of outcomes

- No technology becomes dominant in 100% renewable systems at minimum life-cycle cost
- 100% renewable mixes more economic than current ones
- Demand-side management: most economic and appropriate tool to cover the few deficits
- Planning is necessary for economically optimum mix
- Power grid should adapt to a renewable system
- Energy system integration would get big energy savings and would cut total cost
- Renewables will have to regulate in order to be main elements in power generation system
It is feasible to raise a power generation system based 100% in renewable energies, to cover electricity demand as well as total energy demand.

Total costs of generated electricity are perfectly acceptable and very favourable with regards to business as usual.

There are enough tools to guarantee demand coverage.
Mandatory energy planning targets for Spain:

- Renewables for primary energy: 30% 2020, 80% 2050
- Renewables for electricity: 50% 2020, 100% 2050
- Renewables for building heating & cooling: 80% 2050
- Efficiency: cut demand by 20% 2020

CO2 emission reduction targets for the EU: 30% by 2020 re. 1990