Social, economic and environmental impacts of the promotion of renewable energies in Spain

Ex Post and Prospective Analysis

Background

• INER project, Spanish R+D Plan

• PER 2005-2010. Objectives: 12.1% Gross energy consumption
  30.3% electricity production; and
  5.83% biofuels of the consumption in transport

Instruments: fiscal support, tax exemptions and FIT

Evolution of the Spanish electricity system from 2005 to 2013

40% in 2013
1. Ex Post analysis

Cost assessment of the most recent energy policies in Spain not only considering the private costs of electricity production but also the environmental and socioeconomic costs

2. Prospective analysis

Optimal electricity system in the medium and long term under different scenarios
Ex Post analysis- Methodological approach

Steps

1. Levelised Electricity Costs (LEC)
2. Environmental externalities (LCA and ExternE)
3. Socioeconomic externalities (I-O, WIOD)

**Total (LEC+CA+SEB) costs by technology in 2010**
### Partial Cost Benefit Analysis

<table>
<thead>
<tr>
<th>Relevant factor</th>
<th>Cost or benefit for society</th>
<th>Measurement indicators</th>
<th>Monetized (method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity generation costs</td>
<td>Private cost</td>
<td>LEC</td>
<td>Yes</td>
</tr>
<tr>
<td>Economic activity</td>
<td>Socio-econ externality</td>
<td>Value Added</td>
<td>Yes</td>
</tr>
<tr>
<td>Local environ effects</td>
<td>Environ externality</td>
<td>Various environ impact indicators/Kwh</td>
<td>Yes (Extern-E &amp; Cases)</td>
</tr>
<tr>
<td>Global environ effects</td>
<td>Environ externality</td>
<td>CO2 equivalent emiss/kwh</td>
<td>Yes (Extern-E &amp; Cases)</td>
</tr>
<tr>
<td>RES Support expenditures</td>
<td>Public cost</td>
<td>Feed in Tariff expenses</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Not considered: employment, tax revenues, fossil fuel imports, other renewable support policies, transaction costs, merit order effects, increase in RES exports, rural development
Ex Post analysis- Scenarios

SCENARIOS considered (2005-2010)

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTUAL</td>
<td>The RES deployment throughout 2005-2010</td>
</tr>
<tr>
<td>PER</td>
<td>Spanish energy mix matches the PER objectives</td>
</tr>
<tr>
<td>NO RES</td>
<td>No additional RES plants are installed since 2004 and electricity is now produced with natural gas combined cycle (NGCC) plants</td>
</tr>
</tbody>
</table>
Ex Post analysis- Results

Total costs (private + social)

Huge installation of solar PV technologies from 2007 led to higher cost in ACTUAL scenario

RES support expenditures vs avoided external costs

The costs of FIT exceeded the net environmental and socioeconomic externalities
TIMES- Spain

National energy model built in the framework of the NEEDS project and improved in RES2020, COMET and INER projects. Part of the PET model

One region

Time horizon 2050. In this study, 2035

Twelve time slices: four seasons and day/night/peak

Five demand and two supply sectors

Demand scenarios: energy demand driver projections from the GEM-E3 updated with national data

Trade: electricity exchange with France, Portugal and Morocco

Recently recalibrated to 2005 and updated
### Prospective analysis- Scenarios

#### SCENARIOS considered

<table>
<thead>
<tr>
<th>Scenarios considered</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASE</td>
<td>National and international energy and environmental policies and commitments</td>
</tr>
<tr>
<td>ZERO</td>
<td>No restrictions or targets to emissions and renewable technologies penetration</td>
</tr>
<tr>
<td>INTER</td>
<td>Internalization of the environmental and socioeconomic external costs for all the technologies</td>
</tr>
</tbody>
</table>

#### PER 2011-2020 objectives

<table>
<thead>
<tr>
<th>GWh</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro</td>
<td>31,371</td>
<td>32,814</td>
</tr>
<tr>
<td>Solar PV</td>
<td>9,060</td>
<td>12,356</td>
</tr>
<tr>
<td>CSP</td>
<td>8,287</td>
<td>14,379</td>
</tr>
<tr>
<td>Wind onshore</td>
<td>55,538</td>
<td>70,734</td>
</tr>
<tr>
<td>Wind offshore</td>
<td>66</td>
<td>1,822</td>
</tr>
<tr>
<td>Biomass</td>
<td>7,142</td>
<td>12,200</td>
</tr>
</tbody>
</table>
Prospective analysis- Results

Fossil and renewable technologies production
Prospective analysis - Results

BASE scenario vs PER 2011-2020 objectives

- Biomas, MSW and biogas
- Wind offshore
- Wind onshore
- Ocean
- Solar CSP
- Solar PV
- Geothermal
- Hydro

GWh

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<thead>
<tr>
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<th></th>
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</thead>
<tbody>
<tr>
<td>2010</td>
<td>80000</td>
<td>10000</td>
<td>120000</td>
<td>14000</td>
<td>160000</td>
<td>18000</td>
</tr>
<tr>
<td>2015</td>
<td>100000</td>
<td>12000</td>
<td>140000</td>
<td>16000</td>
<td>180000</td>
<td>20000</td>
</tr>
<tr>
<td>2020</td>
<td>120000</td>
<td>14000</td>
<td>160000</td>
<td>18000</td>
<td>200000</td>
<td>22000</td>
</tr>
</tbody>
</table>
Conclusions and recommendations

Ex Post analysis

RES support policies in Spain have been indeed effective but not cost-efficient. Public support expenditures largely surpassed the avoided external costs considered in the analysis. FIT should be reestablished and better defined according to the external benefits of the technology or/and setting a cap for the installed capacity.

Prospective analysis

It is possible to meet the objectives of renewable technologies penetration and emission reductions set by the European Directives. The internalization of the external costs would anticipate meeting those targets.

This study is being continuously updated introducing new factors in the partial CBA, doing sensitivity analysis for instance in the origin of the goods and services in renewable technology development and other
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Ex Post and Prospective Analysis


Thank you

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Abu Dhabi, 1st-2nd June 2015
Anexes
## CBA data sources and working assumptions

<table>
<thead>
<tr>
<th>Costs and benefits</th>
<th>What?</th>
<th>Methodology</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private costs</td>
<td>Electricity generation costs (c €/Kwh)</td>
<td>LEC</td>
<td>Spanish data</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>International data (OECD, others)</td>
</tr>
<tr>
<td>Socio-economic externalities</td>
<td>Value added</td>
<td>I-O</td>
<td>Spanish I-O (WIOD)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Investment and O&amp;M cost vectors (final demand)</td>
</tr>
<tr>
<td>Environmental externalities</td>
<td>CO2 and other local pollutants</td>
<td>LCA &amp; Extern-E</td>
<td>CASES</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intern. literature review</td>
</tr>
<tr>
<td>Res Support expend</td>
<td>FIT expenditures</td>
<td></td>
<td>Official figures</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>APPA (autoproducers)</td>
</tr>
</tbody>
</table>
PRIVATE COSTS: Levelized Electricity Cost

Where:

\[ LEC = \frac{\sum_{t=1}^{n} \left( I_t + M_t + F_t \right)}{(1+r)^t} \]

- \( LEC \) = Average lifetime levelized electricity generation cost
- \( I_t \) = Investment expenditures in the year \( t \)
- \( M_t \) = Operations and maintenance expenditures in the year \( t \)
- \( F_t \) = Fuel expenditures in the year \( t \)
- \( E_t \) = Electricity generation in the year \( t \)
- \( r \) = Discount rate
- \( n \) = Life of the system

SOCIO-ECONOMIC BENEFITS: Input-Output (W. Leontief, 1939)

- Accounts for the direct and indirect effects
- Captures impacts on economic activity, V.A., employment, etc
- Investment and O&M cost vectors for all technologies & input-output table
- Important advantages & limitations

\[ X = (I - A)^{-1} Y \]

\[ L_i = R(I - A)^{-1} Y \]
Life Cycle Assessment. LCA.

**INPUTS**
- Raw materials procurement
- Production
- Use/Reuse/Maintenance
- Recycling
- Waste management

**OUTPUTS**
- Atmospheric emissions
- Liquid effluents
- Solid wastes
- Co-products
- Other wastes
ExternE. Impact pathway approach

Starting from the emission of a pollutant, the ExternE methodology simulate the transport and transformation in the atmosphere using atmospheric dispersion models.

Impacts in physical terms are then calculated using dose response functions.

Monetary valuation of different impacts is used to estimate externalities in monetary units.
LEC projection

![LEC projection graph](image)

- **EuroCent/kWh**
- **Sources:**
  - Hydro
  - Nuclear
  - Coal
  - Fuel
  - Gas GT
  - Gas CC
  - Small hydro
  - CHP
  - Wind
  - Solar PV
  - CSP
  - Biomass

- **Years:**
  - 2010
  - 2020
  - 2030
Total socio-economic impacts for different electricity technologies (2010)

Environmental impacts for different electricity technologies (2010)