

Summary

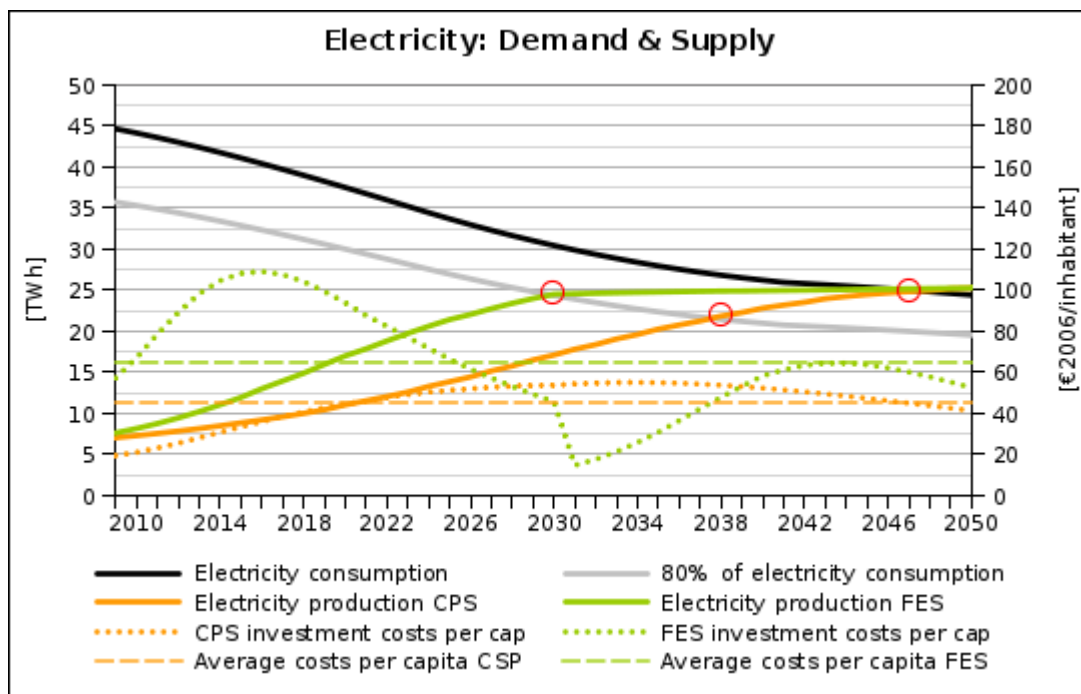
The objective of initiating this study is to show that Catalonia is able to supply its own need for electricity from renewable sources and that this is more a question of advancement than one of retrogression. Giving such a fact-based vision of a future energy supply is very important to influence the discussion about the change from fossil/nuclear energy sources towards a sustainable energy system, especially, as the ongoing discussion regarding the possibilities of renewable energy and efficient design has been negatively influenced by a lack of facts about the availability and potential of these technologies.

Although Catalonia showed a strong economic growth within the past, Catalonia did not perform well with regard to energy intensity. It is quite clear that energy intensity in the Catalonian economy must be reduced in order to shift to a sustainable energy supply and to make it's own contribution to climate protection. The scenarios within this work highlight a development towards halving electricity intensity in the three most important sectors of electricity consumption until 2050. This, of course, means making great efforts to improve the efficiency of electricity use, but we are convinced that this is feasible from a technological point of view. Further technological development towards more efficient appliances will assist such a development and restructuring our economies and redefining the relationship between energy consumption and wealth may be necessary but, in the end, climate change and it's serious consequences will force us to walk this way. After all one fact is quite clear: we have to start now in order to keep transition smooth and to avoid the most serious consequences of climate change.

Taking the development as proposed here will bring down Catalonia's electricity consumption to the 1993 level until 2043 and to about the half of 2007's electricity consumption by 2050. Even with respect to the facts, that further reductions will be harder to achieve the further we step into future and that a certain level of energy intensity will remain, the developments presented here show two remarkable facts: although getting energy intensity down to the half sounds very hard, most of the way solely consist of revoking the increase in energy intensity we saw in the past. The remaining effort in efficiency improvements is not of an extend that should make us doubt that this goal can be achieved. In fact the efficiency target used in this work is almost in line with the EU efficiency target, which aims at increasing energy efficiency

by 1.5% per year¹. Translated to energy intensity the EU target results in decreasing energy intensity to 54% of the 2009 level until 2050.

Both scenarios show the feasibility to achieve a fully renewable supply until 2050. This is not a matter of potentials, but it is a matter of setting and pursuing ambitious goals, encouraging policy and people and – of course – the financial investments Catalonia and it’s people are willing to take. The scenarios show that the financial aspect is not that big obstacle that one might expect. With an annual investment into renewable capacities peaking at 109 €₂₀₀₆ per inhabitant in the “Fast Exit Scenario” and 55€₂₀₀₆ / cap in the “Climate Protection Scenario”, the financial burden to achieve a clean a climate friendly electricity supply in Catalonia is moderate in our point of view (see Picture 1). It must be stated her that these costs are pure investment cost for renewable generating capacities. Neither there are other costs included (e.g. operation costs), nor are there cost savings in other parts of energy supply system considered, such as fuel savings and the related cost reduction or savings in the external costs of energy supply.



Picture 1: Development of electricity demand and supply in the scenarios. Source: SolCat II; 2009.

These financial figures are only the peak investments during the whole development considered here. Calculating the average annual payments for the two different scenarios result to 45 €₂₀₀₆ per inhabitant and year in the “Climate Protection Scenario” and 65 €₂₀₀₆ per inhabitant and year in the “Fast Exit Scenario”.

¹ Source: Action Plan for Energy Efficiency: Realising the Potential [COM(2006) 545]; 2006

Compared to the Catalonian Gross Domestic Product (186,324 million € in 2008, on 2006 price base) the annual costs of the scenarios are 0.19 % of the GDP for the “Climate Protection Scenario” and 0.27 % for the “Fast Exit Scenario” on average. In contrast to the resulting costs, the development - as described in the scenarios - will create jobs² and will lower the export of capital by reducing costs for imported fossil fuels.

Any energy supply system must guarantee sufficient production and distribution of electricity, heat and fuels to meet the demand for energy at any time throughout the year, usually using different energy conversion technologies. Energy is supplied in the form of electricity, heat or fuels, with heat and fuels having the advantage that both can be stored for later use and can be easily transported. So it is not necessary to consume heat and fuels immediately or directly at the production site. Heat can be stored in thermal reservoirs and distributed via district heating networks. In contrast to heat and fuels, which dissipate with time - thus setting a limit to storage time and distribution distance -, fuels from biomass or hydrogen does not have this limitation in storage time or in transport (depending on the fuel type - solid, liquid or gaseous), but storage losses must be considered too.

The situation is completely different with electricity. The necessity of producing enough electricity, on demand and on time, makes this type of energy the most critical component in an energy supply system. While electrical transport via the public grid is quite unproblematic, storing electricity directly on a large scale is material- and cost-intensive. However, storage in batteries and accumulators can involve the use of toxic substances. Therefore this option is not considered here as it is not appropriate for a sustainable energy supply system. Indirect storage can be used, e.g. pumped hydro-storage systems³.

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

² The German example show this job creating effect impressively.

³ Electric mobility was also not considered although electric cars can be used as a storage in electricity supply.

cogeneration and other energy sources can use fuel from renewable sources (e.g. hydrogen or biomass).

The challenge in designing a highly renewable electricity supply system (up to 100% renewables or more for exporting electricity) is to find the combination where advantages of each renewable source sum up to a functioning and reliable system, while disadvantages are balanced out. Especially in the electrical system the need for reserve capacities, necessary as a back up for fluctuating sources, can be minimised by choosing the right combination of renewable technologies to minimise fluctuations and the introduction of demand management to get a better alignment between production and demand.

In this study we only studied the dynamical behaviour of the electrical system in the scenario “Fast exit”. This was done without optimizing the electrical energy system in general but, e.g. for wind energy, best locations were chosen among those that are suitable for installation. This simulation was done continuously for one year with typical weather of the year 2006⁴. Demand management is also included in the energy supply model. As there was no detailed simulation of single consumers, the basic assumption is that demand side management will be able to cut peak loads in electricity demand by 10% without changing the absolute amount of energy consumed in a year (load shifting).

Taking the results of the simulation according to the “Fast Exit” scenario, the system is capable of supplying all the electricity demand in Catalonia. While solar power shows its best performance from late spring to autumn, Wind energy performs best during late winter and early spring, remains on medium level until late summer but drops considerably then. Late autumn again shows days with higher wind energy performance on occasion.

Due to the strong spring and summer performance of fluctuating suppliers (solar and wind) it is often the case that photovoltaics, solar thermal power and wind energy can supply the total electricity demand or even more.

The distinct seasonal variations of the fluctuating part of the supply system force the adjustable part of electricity supply to show a contrary behaviour: Hydropower,

⁴ Source: [MeteoCat; 2006]: *Servei Meteorològic de Catalunya* (Dades EMA integrades a XEMEC). Departament de Medi Ambient i Habitatge

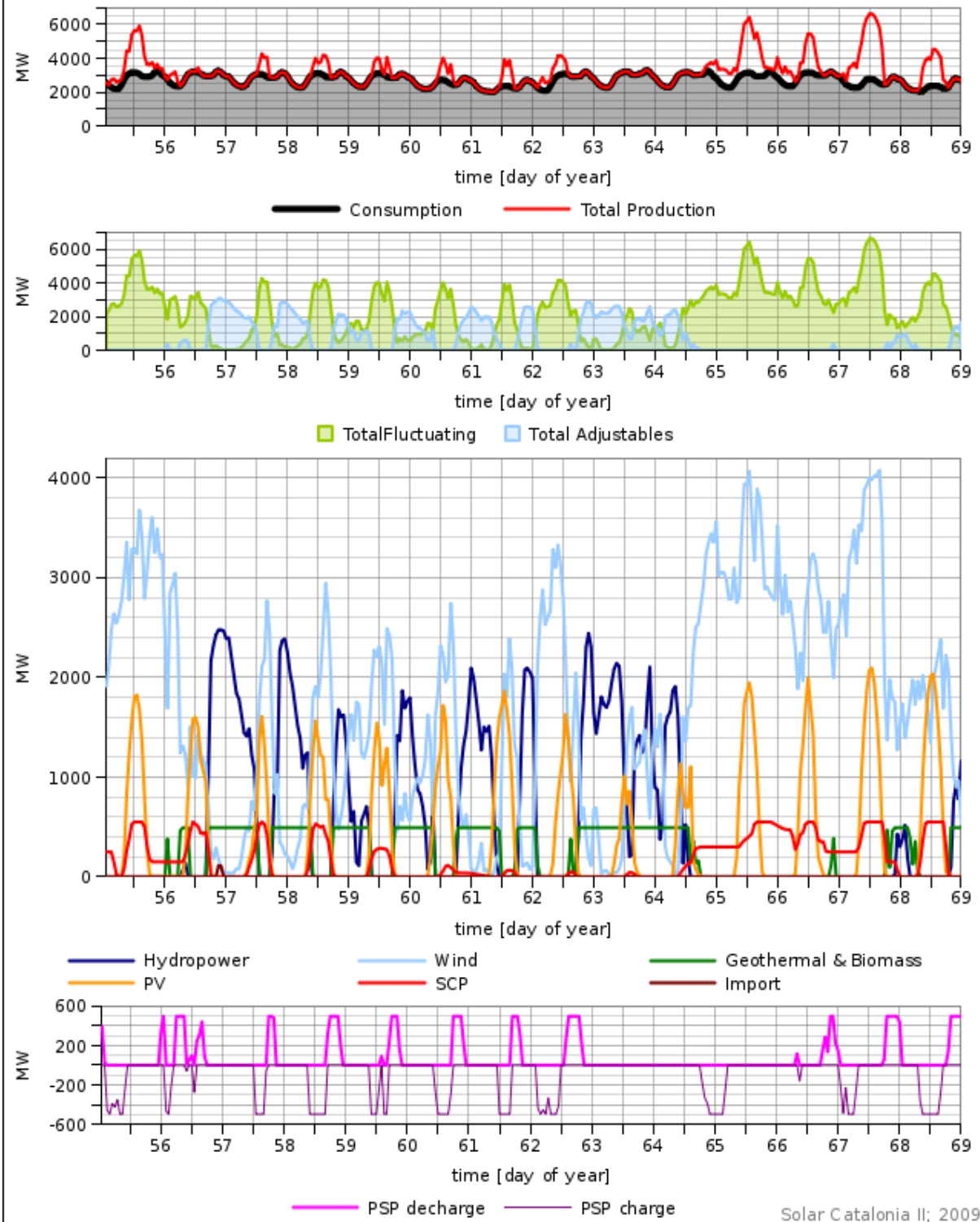
Geothermal & Biomass and Imports⁵ (from other regions in Spain or France) have to contribute more during autumn and winter.

From autumn to late winter the adjustable suppliers have to contribute most to electricity supply, as the decrease in solar irradiation appears in conjunction with generally lower wind speeds. Looking at the big picture the climate variation over the year, with strong wind performance especially in late winter/early spring, good solar and medium wind performance during the warm periods over the year, favours a system as described here, as the adjustable suppliers (hydropower, geothermal and biomass) have to contribute most during those times when they can be operated in the best way. While a high utilization of hydropower coincides with higher precipitation levels, geothermal- and biomass plants can mainly be operated during times with a higher demand for heat, thus giving the opportunity to take advantage of high efficient combined heat and power plants.

Basically an electricity supply system with a high share of fluctuating suppliers benefits from a strong interconnection with neighbouring regions and countries. It is likely that surpluses from fluctuating sources, and deficits due to the breakdown of fluctuating supply too, will not occur simultaneously in all regions of wide and strong connected area. Therefore strong connections for electricity transport will be a key issue for compensation of fluctuations as they enable the export of surpluses to such regions with an actual deficit. Nevertheless each single region should be optimized with regard to fluctuations in it's own electricity supply.

⁵ The simulation considers the possibility to import electricity from neighbouring regions and/or countries. To reduce imports it would also be possible to further increase the generating capacities in Catalonia itself.

Simulation results, week 9 - 10



Annual variations of the Supply System

