Prediction Model for the Electrical Industry in Spain—The Trend Toward Renewable Energy

M.A. Verdejo and J. Fernández

ABSTRACT

During 2008-2013, the global economic crisis and financial uncertainty brought important economic adjustments in developed countries and especially in the European Union (EU). Currently, however, key national and international agencies predict the consolidation and acceleration of growth of the European economy during 2014-2015, driven by recovery of trust and improved financial conditions.

According to the report of the International Energy Agency (IEA) and the reports of Spanish energy sector, final demand for electricity dropped 3.4% in 2013 over the previous year, which was evidence of lower economic activity and structural differences in consumption.

The final electricity demand in 2013 was 232,008 GWh, down 3.4% from the previous year. However, the forecast for 2014 and 2015 foresees an increase of 1.5%, which will influence the changing trend model of the electricity industry in Spain.

This model allows predicting the potential political and economic implications, which are dependant on the discussed variables. The most influential parameters that have been considered to establish the prediction model are: absorption and emission of carbon dioxide, forest cover, demand and primary energy intensity, energy carriers (coal, fuel, gas, hydro, nuclear and renewables), gross domestic product and rates, and energy vectors for all the variables in the period. The results clearly show that sustainability will be a fact when making energy efficiency programs, both in the electrical industry as in other energy sectors. Additionally, CO_2 emissions will be reduced if proper action plans and efficiency policies are developed.

In evaluating scenarios proposed in this article, the model con-

cludes that the efficiency scenario will save 107 Mt CO_2, which will save €1.07 billion, according to the average estimate of the price of emission rights in the European Union.

INTRODUCTION

Power generation and its environmental impact are matters of global concern. Greenhouse gases—products of the electrical industry—cause great impacts on the environment, the landscape, soil, agricultural processes, and human health. We must advance the technology of electricity production but bear in mind at all times that protecting our environment is paramount. [2]

The objective of combating climate change is at the core of ongoing policies, and its achievement is directly connected to all the other objectives set by the EU for 2020 (20% of renewable energy, 10% of biofuels, 20% saving and efficiency energy, as well as additional measures such as CO_2 capture and storage). [3] Many of these objectives are directly related to electrical energy production.

The European Union has adopted a strategic stance of great significance and courage to take on the environmental challenges and the fight against climate change as central elements of this energy policy. The risks associated with climate change are such that the EU has decided to address them immediately. The objectives that are being established are increasingly ambitious: reducing emissions by 20% compared to 1990 levels by 2020, reducing emissions by 80% by 2050, and a carbon-free economy. [4]

The latter objective could be increased with a post-Kyoto agreement to reduce the GHG emissions by 80% in 2050, to limit soil temperature increase below 2ºC compared to preindustrial levels. It points to an average growth of electricity demand of 1.5% annually over the period 2009-2014, 2.7% in the period 2015-2020 and 3% by 2030, as recommended by the International Energy Agency and the International Monetary Fund. [5]

According to the national allocation plan for emissions trading, in Spain, in the period 2008-2012, emissions should not exceed more than 24% of 1990 emissions [3,6,8]. This value is obtained considering the Kyoto Protocol objective (+15%), the estimates of absorption by sinks (a maximum of 2%), and the credits to be obtained in the international market (7%). These data provide a realistic idea of the future outlook in Spain if no other restrictions are applied to reduce the CO_2 emissions.[7,11]

Most forecasting models are based on assumptions—in many cases certainly reliable and of great value—but which involve no political, economic and environmental energy variables, as done in this work. The Spanish energy model is very specific and requires an independent study for other countries due to Spain's large energy dependence.[9,10]

The parameters considered most influential for establishing a prediction model in the short term are absorption and emission of carbon dioxide, woodland, demand and primary energy intensity, energy carriers (coal, fuel, gas, hydro, nuclear and renewable energy), gross domestic product and energy carriers and rates for all variables in the period considered (2004-2030).[11]

In this work, the energy situation in Spain is analyzed considering the strategies to obtain a sustainable energy system in both economic and environmental aspects.

METHODOLOGY

The aim of this study is to analyze scenarios of electricity generation in Spain to 2030 and quantify its impact on the three axes—supply security, economic efficiency, and environmental sustainability—to extract guidelines that can help in the development of strategic plans near- and long-term.

The analyzes were performed on multiple scenarios, using a model that calculates the energy balance based on the generator park designed in each scenario. The model obtains economic indicators such as investment and operating costs; the CO_2 portion of renewables; and security of supply energies (coverage ratio, degree of self-sufficiency, diversification).

This process performs the following steps:

- Uses the electricity market to obtain adequate signals about energy prices;
- Highlights the role of renewables in future demand coverage;
- Predicts savings and energy efficiency improvement;

- Encourages positive involvement of regulatory agencies to ensure a level of permanent coverage of electricity demand;
- Provides support for R&D in advanced energy technologies;
- Encourages prudent use of coal and nuclear technologies in the transition towards a sustainable model; and
- Promotes compliance with international commitments.

According to the green paper, "A European Strategy for Sustainable, Competitive and Secure European Communities," six key areas are identified to address the four challenges of sustainable energy models in European Union countries (including Spain):

- Competitiveness and the internal energy market
- Diversification of energy mix
- Solidarity
- Sustainable development
- Innovation and technology
- Foreign policy

The European energy policy should have three main objectives:

- Sustainability: Development of competitive renewable energy sources, plus containment of energy demand in Europe and leading global efforts to tackle climate change and improve local air quality.
- Competitiveness: Ensuring that opening the energy market is beneficial for consumers and the economy in general, while at the same time stimulating investment in clean energy production, increasing energy efficiency, mitigating the impact of increased international energy prices in the EU, and keeping Europe at the forefront of energy technologies.
- Security of supply:
  - — Slowing the growth of EU dependence on imported energy through an integrated approach to reducing demand;
  - — Diversifying types of energies consumed ("energy mix") through greater use of indigenous energy and competitive re-

newables and diversification of routes and sources of imported energy supply;

— Creating a framework that encourages the right investments to meet growing energy demand;

— Improving the equipment of the EU to cope with emergency situations;

— Improving the conditions for European companies seeking access to global resources.[12,13,14]

The results of the energy model have been obtained using the tool "Globesight" (Figure 3), which is short for Global Foresight and has been developed by the Case Western Reserve University (Ohio, USA). It is presented as a "Reasoning Support Tool" (Mesarovich, 1996; Sreenath, 2001) (Figure 1).

The tool represents the physical environment in interaction with the population growth, energy, and the development of GDP. Its concept requires actors to be actively involved in the operation of the system because they must provide subjective and qualitative elements. It is the so-called "human-in-the-loop" system. The study was implemented in

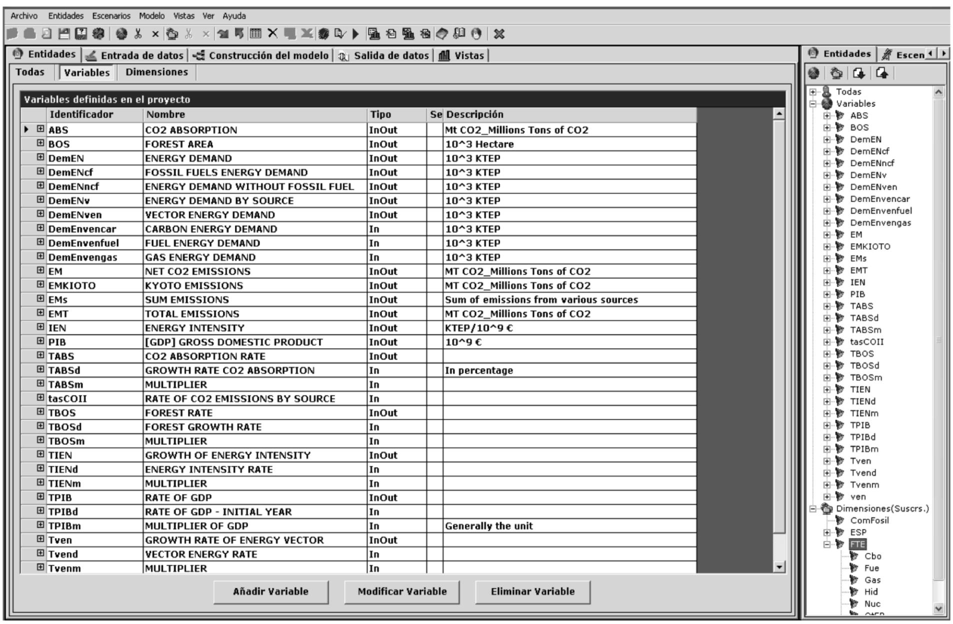


Figure 1: Mesarovic Globesight. Variables defined in the methodology

models of global environmental impact (Philip J.J. AÑO) and for educational purposes by UNESCO.

Their system is based on: demographics, energy, economy (GDP) and combines and interrelates two selected systems, energy and environment. It applies the variables in the area of system representation through multi-level hierarchical models (Mesarovic, 1970.1972; Xercavins, 2000) and its implementation using decision-making support tools.

APPLICATION OF THE METHODOLOGY OF THE ENERGY MODEL IN SPAIN

Once the set of variables that affect the environment for each electricity generation technology have been identified, the next step is to determine how to distribute their effects and how they can be implemented to achieve the objectives, interacting with the energy policies, to be taken into account on the top level of the analysis.[15]

Three levels of analysis can be identified in the model structure (Figure 3):

- Model Level 3. Known input variables. The GDP of Spain and pollutant emissions from various electrical generating sources.
- Model Level 2. Results derived from Level 3, implemented in the program. Net Emissions.
- Model Level 1. Results derived from Level 2 and implemented with the planning model of energy sustainability.

A variance partition is done, converting a portion of it in systematic variation, and the other is split according to their sources of variation: emissions, GDP, and generation sources. The predictions are vital for the demand forecasting, actions in energy plans and evaluation of data obtained under the different models and scenarios that arise in this work.[16,17]

The main structure to be used for the timing of the variables in the model is defined through a formula that relates the data of a certain year with the forthcoming years. Primary Energy Intensity (PEI), shows how it evolves over time, and it can be observed on the first level of Equation (1).

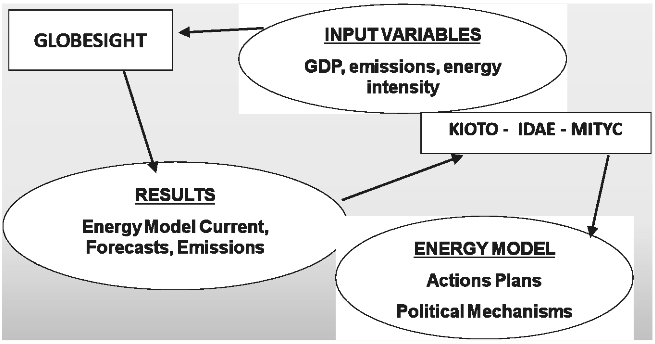


Figure 2: Structure of the model

$$PEI_t = PEI_{t-1}\left[\left(\frac{GPEI_{t-1}}{100}\right)+1\right] \qquad \text{Eq. 1}$$

where PEI_t is the primary energy intensity in year t and $GPEI$ is the growth rate of primary energy intensity in percent.[18]

MATHEMATICAL MODEL STRUCTURE

The data of the primary energy intensity for a certain initial year are known from statistical sources. The value of the rate of growth is more uncertain, and it is obtained from the growth statistics of recent

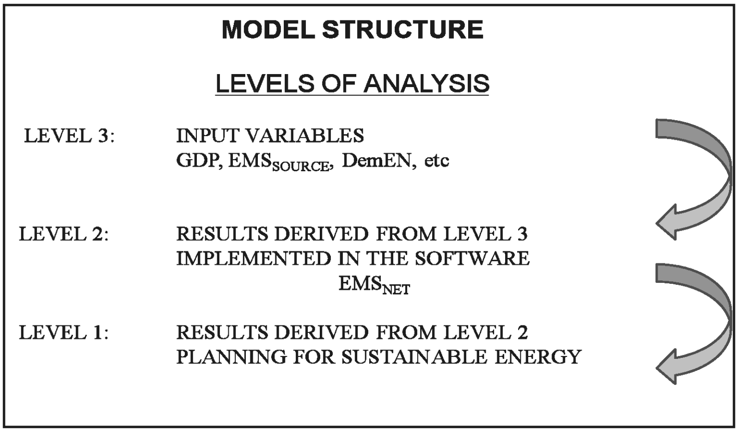


Figure 3: Methodology. Variables and levels of analysis

years, selecting the data from various forecasts and relevant sources. To eliminate as much as possible the uncertainty in the value of the rate of growth, the model includes a new formula with variable rates.

$$GPEI_t = GPEId_{t-1} \, GPEIm_{t-1} \qquad \text{Eq. 2}$$

where $GPEI_t$ is the historical growth rate of primary energy intensity and $GPEI_m$ is the multiplier. [Figure 4]

The historical growth rate of the variables is selected based on the analyzed data from official statistics or other reliable and proven sources.[3,4] The multiplier *GPEIm* has by default a unity value, indicating that the outlook for the variable chosen future will be similar to the past historical behavior. If one has evidence or reliable data to establish that the variable will take a very different historical growth, variations in the multiplier can be included that change the rates to be established. In this way, one can create different forecasting scenarios for later analysis, thus presenting possible future changes in the studied variables.[19]

It is believed that the energy demand can be classified in two types, depending on its origin being fossil fuels or not. That is, it is extrapolated from the energy demand, which in turn is derived from the production of energy sources that harm the environment and sustainability and from those that do not harm the environment and can improve it.

$$DemENven_t\,(r)(f) = ven_t\,(r)(f) \times DemENv_t\,(r)(f) \qquad \text{Eq. 3}$$

where $DemENven_t\,(r)(f)$ is the energy demand by source, in Ktep, $ven_t\,(r)(f)$ is the energy vector by source in per unit and $DemENv_t\,(r)(f)$ is the total energy demand by region and source.

It also calculates the energy demand, distinguishing the supplies that use fossil fuels (coal, oil and gas) from the demand that comes from sources that do not use fossil fuels for the energy production.

$$DemENcf_t\,(r) = DemENvencar_t\,(r) \times DemENvenfuel_t\,(r) \times DemENvangas_t\,(r) \qquad \text{Eq. 4}$$

where $DemENcf_t\,(r)$ is the demand for energy with fossil fuels, $DemENvencar_t\,(r)$ is the energy demand with coal, $DemENvenfuel_t\,(r)$ is the en-

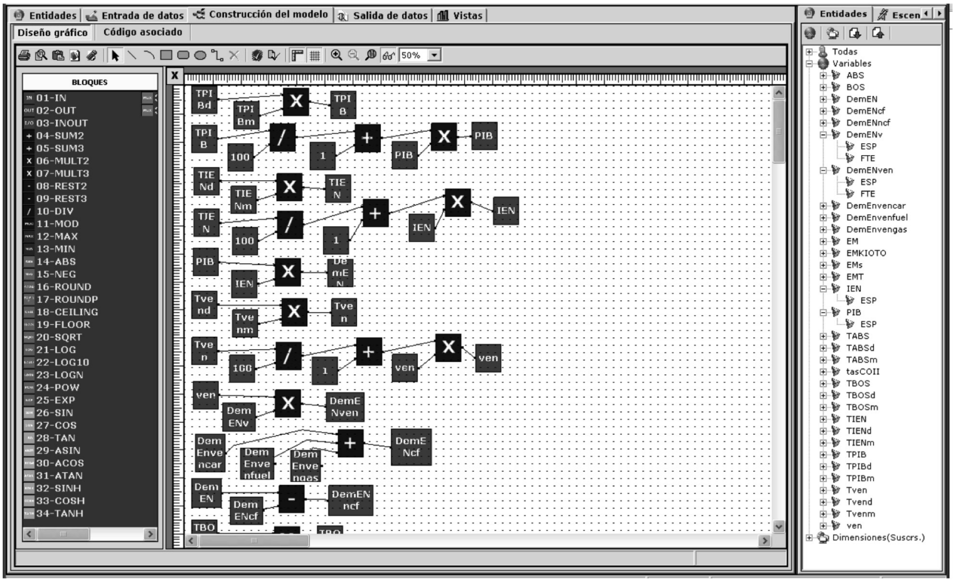


Figure 4: Graphic Model

ergy demand with oil, and *DemENvengas*$_t$ *(r)* is the energy demand with gas. All values in Ktep.

It is important to carefully select the variables used in the model, based on the rigor and research. To this end, data are taken from official reports of the IEA (International Energy Agency) and other institutions, which have allowed choosing the variables that provide a strict and reliable energy model.[20]

IMPLEMENTATION OF ENERGY AND ECONOMIC VARIABLES IN A MODEL

The model is divided into several structures and forecast scenarios. It begins by analyzing the first variables and consequences, and with the obtained results different situations and submodels are built.[21,22]

The main results obtained are the primary energy intensity; primary energy demand with and without fossil fuels; and the value of absorptions and carbon dioxide emissions for different technologies, sources and territories. The major environmental factors studied in the discussed model are the emissions of polluting gases, focusing on carbon dioxide because it accounts for the largest environmental problem for the proposed sustainable energy model.

Carbon dioxide emissions are the main output variable and one of the biggest problems facing the electric power industry in Spain, now and in the long term. Historically it is found that economic growth is highly correlated to the growth in emissions of greenhouse gases.[23]

Spain ratified the 1993 UN Framework Convention on Climate Change (UNFCCC) in 1992 and 2002, and the Kyoto Protocol in 1997. In accordance with the agreement of "shared responsibilities" between EU governments, and in compliance with article 4 of the Kyoto Protocol, Spain agreed to limit the growth of net emissions of greenhouse gases (GEI) 15% above 1990 for 2008-12. Carbon dioxide accounts for 80% of these emissions.

With these data, the current emissions model is outlined, an analysis of recent years' growth is made (shown as the growth rate of emissions), and the net absorptions due to forest growth in Spain are defined (these are subtracted from the emissions due to burning and other processes). Another aspect to be taken into account is the absorption of carbon dioxide from carbon sinks. A sink can be defined as any system or process where the air is extracted from the gas or gases and stored. Vegetation acts as a sink for major life function, photosynthesis.

Using this function, the plants absorb carbon dioxide, compensating for losses from the breathing process and other natural processes such as the decomposition of organic material. The Kyoto Protocol considers the activities of land use, changes in the land use, and forestry (LULUCF) as sinks. Although net absorption from forests does not produce an effect that can be considered as important compared to the total net emissions, it is considered in the calculation.

In Spain, absorptions by sinks account for approximately 10% of total emissions from anthropogenic effects. With all the data analyzed and inventoried, this study evaluates the effects of pollutant emissions on the current energy model, which directly influences the energy demand of the region's gross domestic product rate, woodlands.

Spain and the autonomous communities are considered as a region. The study takes into account that regions calculate their GEI in terms of emitted gases, not consumed ones. The energy model also cal-

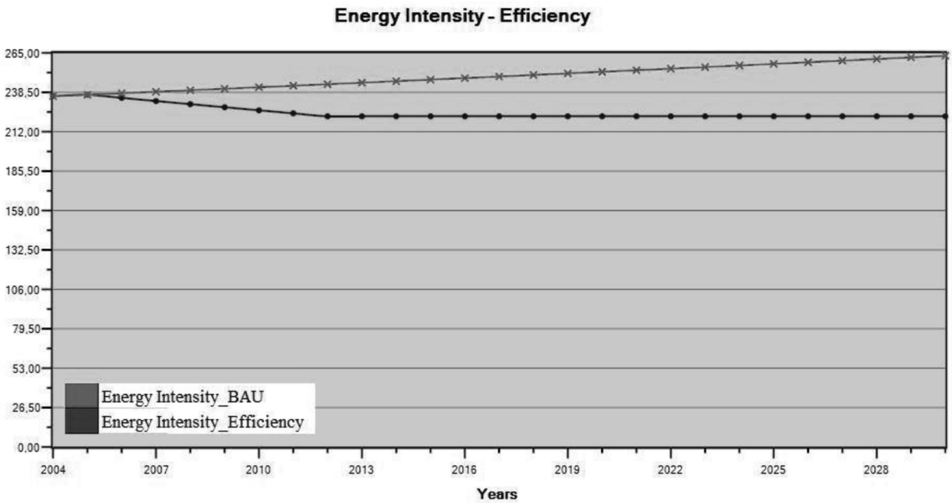


Figure 5: Energy Intensity Scenarios (Ktep/10^9€)

culates the carbon dioxide emissions by fuel type, detailing the source of emission.

In the definition of the proposed model, several hypotheses have been made:

- The requirements of the Energy White Paper in Spain to build the energy model and the Green Paper on European Strategy for sustainable, competitive and secure energy production.
- Growth rates that start with the model trend have been obtained from the statistics since 1995. However, to eliminate uncertainty as much as possible, the model includes a new formula that allows calculating a variable rate.
- The main scenario that is considered offers the results until 2030, and references will be used for other scenarios.
- The main results obtained are the primary energy intensity, primary energy demand (with and without fossil fuels), the value of takeovers, and carbon dioxide emissions for different technologies, sources and territories.

Despite the difficulty of linking the considered variables and the limitations and restrictions that involve the interaction of different data (economic, energetic and environmental), the model reflects quite closely the expected results, compared with other studies and previous research using prediction models and plans.[24,25]

The proposed model has many applications, and it is very flexible, since to simply change any of the used data, either energetic or economic, leads to a new scenario forecasting.

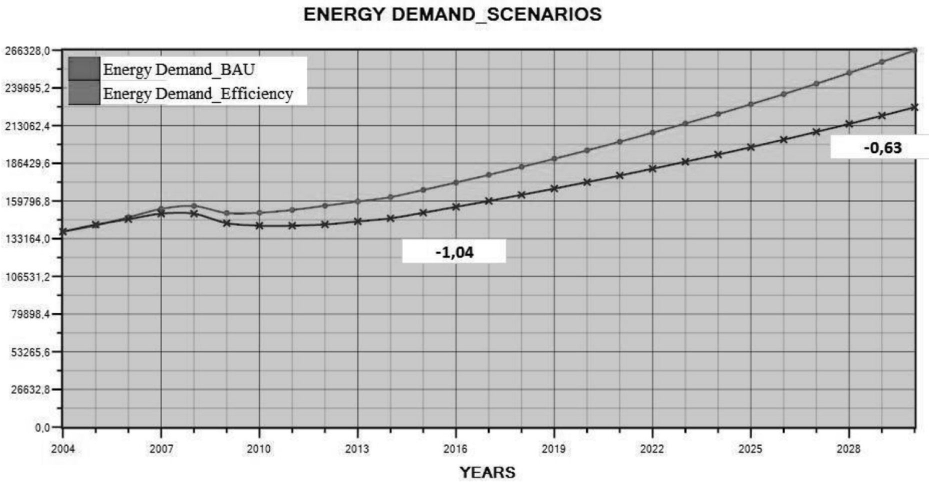


Figure 6: Energy Demand Scenarios (Ktep)

ENERGY INTENSITY ASSESSMENT BY THE EFFICIENCY MODEL

The variation of the 2004-2012 energy intensity is –0.9% per year, stabilizing in 2013 and maintaining its value until the end of the period, 2030. In this way, it is lowered from 236 Ktep/10^9€ in 2004 to 222 Ktep/10^9€ in 2030. (Figure 5)

This downward trend will cause a decrease in direct proportion to the primary energy demand, which will lead the country to move towards an efficiency scenario similar to other countries in the EU-15.

Figure 6 shows that the upward trend in energy demand has been reversed, compared to baseline values. The growth rate of the efficiency model compared to the trend model implies a decrease of –1.04% from 2004 to 2016 and –0.63% from 2017 to 2030.

Figure 8 refers to the total emissions from consumption of fossil fuels (EMs), total emissions minus removals due to the Spanish forests (EMT), and emissions that the Kyoto treaty has established as viable and efficient indicators (EMKIOTO). In the energy model, carbon dioxide emissions are calculated by fuel type, detailing the sources of emissions. (Figure 8)

$$EM_t\ (r)(f) = \text{tas } CO_2(f) \text{ x } [PEI_t\ (r) \text{ x } GDP_t\ (r)] \qquad \text{Eq. 5}$$

where EM_t *(r)(f)* are carbon dioxide emissions by region and source; *tas* CO_2 *(f)* is the rate of carbon dioxide by source, PEI_t *(r)* is the primary energy intensity by region, and GDP_t *(r)* is the gross domestic product by region.

Equation (5) relates the carbon dioxide output with the economic activity through the gross domestic product and the energy intensity of each considered region. The rate of emissions by source is obtained from statistical data, clearly defined in different analytical studies for each energy source.[7,17,24]

In order to relate the total anthropogenic emissions one must add all of them by source.

$$EMs_t\ (r) = \sum_t EM_t\ (r)(f)[EMs_t\ (r) = \sum_t EM_t\ (r)(f)] \qquad \text{Eq. 6}$$

where EMs_t *(r)* are gross emissions by region and EM_t *(r)(f)* are the carbon dioxide emissions by region and source.

In this way the total gross emissions due to fuel consumption is obtained. The net emissions can be determined subtracting the absorptions due to carbon sinks.

$$EMT_t\ (r) = EMs_t\ (r) - ABS_t\ (r)] \qquad \text{Eq. 7}$$

where EMT_t *(r)* are the net emissions by region and ABS_t *(r)* are the removals by region due to carbon sinks.

The calculation of CO_2 removals taking place in the woods is done through the recommendations of the Report of the Ministry of Environment of Spain, in its study on the emission inventories of greenhouse gases in April 2003. It is accounted for by statistical National Forest Inventory, net annual increment in the volume of live biomass in wooded

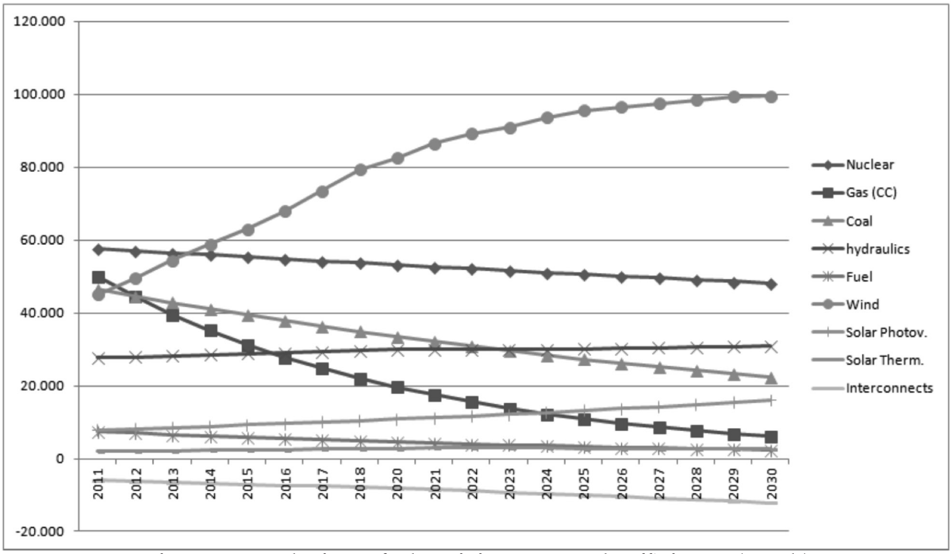


Figure 7: Evolution of Electricity Demand. Efficiency (GWh)

areas of major and minor feet, as well as the surrounding vegetation of bush type.

$$INABT = \{VCC \times 1{,}6 \times (^{1AVC}/_{VCC}) + [(Cant.p.m.) \times 0.00314 \times 0{,}02 \times 1{,}4]\} - \{1/2 \times (Cortasmad) \times (1{,}28539) \times 1{,}6\} \quad \text{Eq. 8}$$

where **INABT** is the net annual increase of fresh biomass, m^3, ***VCC*** is the volume of timber with bark trunk, m^3, ***IAVC*** is the net annual increase of *VCC* (m^3 per year), ***1.6*** is the factor used to expand timber volume over bark to total live tree biomass, including the surrounding scrub vegetation, ***Cant.p.m.*** is the number of minor feet inventories in the 2º IFN (National Forest Inventory), ***0.00314*** is the estimate of the volume of the trunk of a foot less representative m^3, ***0,02*** is the annual growth rate of stem volume less representative of one foot, ***1,4*** is the factor used to expand the volume of the trunk of the minor foot beyond their total living biomass, including the surrounding scrub vegetation.

Cortasmad is the volume of a classified part of the timber cutting as shown in the monograph "Yearbook Agricultural Statistics" in m^3; ***1/2*** is the factor that is introduced to take into account the percentage of 50% of cases in which the timber harvesting operation is later in the year of sampling for forest inventory; ***1,28539*** is the ratio *(15458903/12026616)* from the "Yearbook of Agricultural Statistics"—as the ratio of the two values—the variable used to expand variable timber cutting to the total, including those for classified and unclassified wood; and ***1,6*** is the factor used to expand the volume of timber cutting to the total living biomass affected by these cuts.

The end result is the value of net INABT in tonnes of CO_2:

$$INABTF = INABT - Incend \qquad \text{Eq. 9}$$

where *INABTF* is the annual net capitation due to changes in the forests, *INABT* is the net annual increase of fresh biomass and Incend is the loss due to forest fires, all values in tonnes of CO_2.

Figure 8 shows that growth of net emissions in 26 years in Spain is 79% compared to 2004, 36 points less than the Model Trend-BAU, indicating deceased output of 107 million tonnes of CO_2 into the atmosphere. Although these numbers are not close to those required by the EU and the Kyoto Protocol, since the increase over 1990 levels far exceeds those established by the model, it is clear that avoiding this amount of emissions is not ideal, but it is an important value.

The only solution to meet current regulations regarding emissions is to buy that of a third country, a policy that is taking place nowadays to reach the quota established in international treatments.[26]

COMPARISON FOR OTHER STUDIES AND ACTION PLANS

To validate the model, the results are compared with those of other studies of reference. The proposed energy model is implemented with the Globesight software that evaluates measures and trends. This software has been used in other studies such as human evolution, pollution and energy.

The main studies that are referenced to make the comparison with the Globesight are the United Nations Framework Convention on Climate Change (referring to Spain), the Stern Report on climate change applied to Spain, Strategy and Efficiency Savings in Spain (2004-2012, the report World Energy, Technology and Climate Policy Outlook-WETO 2030).

These studies and reports are made primarily for the horizon year

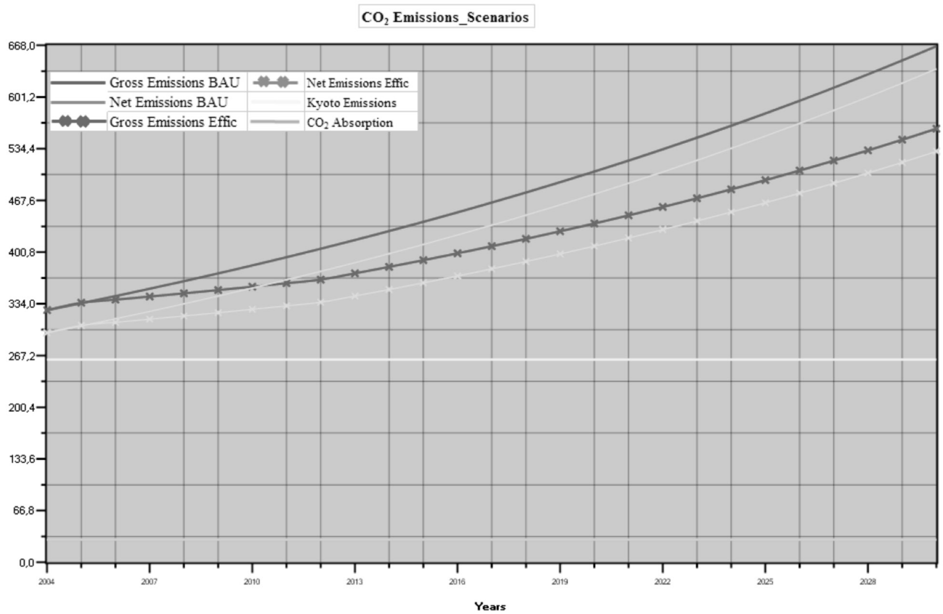


Figure 8: CO_2 Emissions (Mt.)

of 2012, except for the WETO that extends it until 2030 but refers to the EU as a whole, and consequently no comprehensive comparison can be made.[4]. The Action Plan and Energy Efficiency Savings [2011-2020] of the Ministry of Industry, Tourism and Trade of Spain, proposed a primary energy savings in that period by 20% compared to the BAU baseline scenario, which would mean a decrease of primary energy demand in the period of 35.585 Ktep [2010-2020].

According to the results obtained in this work, there was a saving of primary energy for the same period in the efficiency scenario of 30.749 Ktep. This result is significantly lower than the one proposed by the Efficiency and Savings Plan.[28] According to the evolution of consumption and energy intensity proposed by the Action Plan [2010-2020], the consumption of primary energy by renewable energy sources will increase by 12.968 Ktep, a 19.60% increase in the total primary energy mix. In the results obtained in the efficiency model that is proposed in this article, the increase in primary energy coming from renewables is 13.611 Ktep, a 13.48% increase in the primary energy mix.[27]

The report of the United Nations Framework Convention on Climate Change proposes two scenarios for the outcome of GEI emissions.

A scenario "with measures," which aims to achieve savings in 2020 of 68.884 Kt. of CO_2 equivalent compared to a scenario without measures.

In the proposed efficiency model, savings of 70 million tonnes of CO_2 are achieved by 2020. This value approaches with great accuracy the provisions of the United Nations Framework Convention.

CONCLUSIONS

The estimated demand results from an analysis of the evolution of the electric intensity of the Spanish economy, which allows us to assume that the demand for electricity will continue, correlated with economic growth. It points to an average growth in electricity demand of 2.7% per year in the period 2004 to 2030 as the baseline scenario. This is moderate compared to the 3.7% growth in the period 1995-2009.

The growth of renewable energy sources implementing the action plans of sustainable energy, E4 and others, will assume 13.48% of the energy mix in 2030, 16.06% if the hydraulic energy is also considered. This percentage is fundamental to the evolution of efficiency in Spain, although not entirely acceptable, since it is not enough to establish an economic calm as far as CO_2 emissions trading is concerned (Table 1).[30,31]

The mainland electricity balance of January 2014 shows a demand coverage of 28.3% from wind power, 20.2% from nuclear energy, 16.9% from hydropower, 9.4% from coal power plants, and 6.6% from combined cycle natural gas. In relation to the production of energy from renewable sources, according to REE, 11,544 GWh were generated in January 2014, a 49.3% increase over the same month last year (10,183 GWh).

Results clearly show that the main driving forces for energy development in Spain, the energy intensity, GDP, energy demand and CO_2 emissions growth will suffer during the period 2004-2030. This will happen both in the pessimistic trend scenario and in the efficiency scenario, under the government's energy policies, imposed by the Kyoto Protocol and the treaties and allocation of emissions rights in the European Union. [32,33]

Having analyzed the proposal in this work, the cost-benefit scenarios show that in the Efficiency Scenario savings are 107 Mt CO_2, or €1.07 billion.

The market for emission rights in the European Union was estab-

Table 1: Evolution of the main model variables

	Trend scenario			Efficiency scenario		
	2004	2012	2030	2004	2012	2030
GNP (10^9€)	585	728	1176	585	728	1176
Energetic intensity (Ktep/10^9€)	236	244	263	236	222	220
Energy demand (10^3 Ktep)	138	177	308	138	162	261
Fossil fuels demand	113,6 82%	141,8 80%	235,5 76,5%	113,6 82,2%	130,6 81%	198,5 76%
Coal*	14,8%	17,88%	17,46%	14,8%	14%	11%
Oil*	50%	58,98%	54,52%	50%	45,7%	35%
Gas*	17,4%	23,14%	28,02%	17,4%	21%	30%
Other fuels demand	24,4 17,8%	35,2 20%	72,5 23,5%	24,4 17,8%	31,4 19%	62,5 24%
Hydraulic*	1,9%	2,1%	3%	1,9%	2,1%	2,5%
Nuclear*	11,7%	12%	11%	11,7%	11%	10%
Other Renewable Energies*	4,2%	5,8%	8,5%	4,2%	5,8%	11,4%
Gross CO_2	326	405	667	326	365	560
Enissions (Mt CO_2)	+15%	+43%*	+135%*	+15%*	+29%*	+98%*
Kioto Emissions (+15%)	262	262	262	262	262	262
PNA Emissions (+24%)	283	283	283	283	283	283

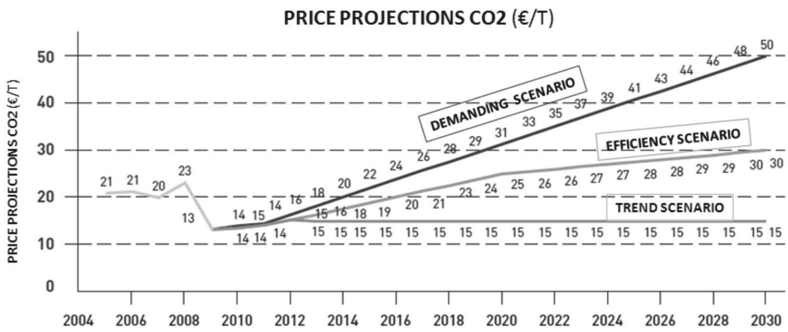
**Increased percentage relative to the values of the National Plan of assignment*

lished with the European Directive 2003/87/EC. The price for the first year exceeded 30 €/tCO_2 in May 2006; during the last years the cost has dropped to levels below 10 €/tCO_2. The explanation for changes in the cost is the influence of the economic crisis. All sectors covered by the European Directive 2003/87/EC have reduced their emissions; only the transport sector's have increased.[34]

The evolution of the price of allowances will also be essential to the future of renewable electricity generation plants (Table 2).

Renewable energy will play a key role in providing new power generation and will contribute decisively to meeting environmental objectives. The Spanish renewables industry faces a period of consolidation as part of the energy mix and growth to meet forthcoming demands. In any future scenario, between 40 and 70% of the new capacity will be renewable and will consume 50-80% of new investment in generation. [35]

Table 2: Price projections. IDAE. 2011



The 2011 technical study by the Institute for Diversification and Energy Saving in Spain states that technologies for generating solar photovoltaic and solar thermal are those that have reduced their costs over the past decade and will continue with this trend until 2030.[36,37]

For thermoelectric technology there is great potential for cost reduction through optimizing the scale of plants, because the size of existing plants (20 MW in the case of towers and 50 MW parabolic trough) is below optimum level.

In the case of photovoltaic technology, the main cost reduction is to improve the efficiency of the photovoltaic panels. Increasing the efficiency will reduce module surface. Crystalline and thin-film technologies will be critical to reducing costs. Also nanotechnology in this equipment could reduce costs by 30% by increasing the efficiency of photovoltaic modules. Analyses of generation costs in solar technology show reductions from an average of 20 c €/kWh in 2010 to 8 c €/kWh in 2030.[38]

The state of renewable energy is at a critical moment that can make its future development. Despite the effects of the economic crisis, renewable energy continues to experience significant growth globally, to the extent that more countries are embarking on plans to develop renewable energy. Included are the EU with its Strategy 20-20-20, China, India (with India Solar Mission), Brazil and the US, where there is an increasing focus on renewable energy penetration with renewable portfolio standards.

Many factors drive governments' development of renewables: 1) the fight against climate change, 2) energy independence and security of supply, and 3) national competitiveness and technological development and job creation. High oil prices only reinforce this trend.

We therefore hope that renewables constitute one of the most important sources of energy and the greatest potential for growth in the coming years.

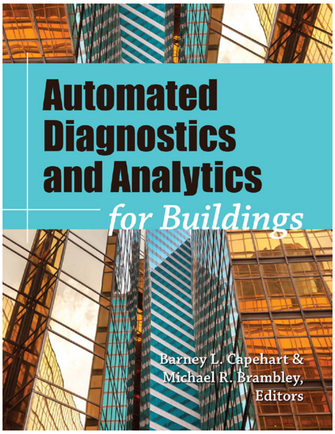
References

[1] Subdirección General de Planificación Energética. Ministerio de Industria, Turismo y Comercio. Evolución del consumo energético en España. (Febrero 2006).
[2] Nieto Santamaría. Evolución de las Emisiones de Gases de Efecto Invernadero en España. (1990-2006).
[3] IDAE. Plan de Ahorro y Eficiencia Energética 2008-2020. Ministerio de Industria, Turismo y Comercio. Gobierno de España. (2011).
[4] European Commission. World energy, technology and climate policy outlook. WETO 2030. Final report.(2010)
[5] IEA, 2010. World Energy Outlook. Spanish Translation. 2010.
[6] IDAE, Estrategia de ahorro y eficiencia energética en España 2004–2012. Plan de acción 2008–2012. Ministerio de Industria, Turismo y Comercio, Instituto para la Diversificación y Ahorro de la Energía. (2007)
[7] A.Z. Mech, S. Rouse. Macro and Micro Economic Principles of the Kyoto Protocol Result. EIC Climate Change Technology. IEEE. (May 2006)
[8] Country analysis. The European environment. State and outlook (2005).
[9] Ministerio de Industria, Turismo y Comercio. IDAE. Estrategia de ahorro y eficiencia energética en España, 2004-2012. E4. Plan de acción 2005-2007. Julio (2005).
[10] Secretaría General de Energía. La energía en España. Madrid, (2004).
[11] I. Kockar. European Union perspective on the Kyoto protocol: emissions trading scheme and renewable resources. Power Engineering Society General Meeting. IEEE. (June 2006).
[12] F. Foidart, J. Oliver-Sola. How important are current energy mix choices on future sustainability?. Case study: Belgium and Spain—projections towards2020–2030. Energy Policy (38). 5028–5037. (2010)
[13] Communication from the Commission to the council and the European Parliament. The share of renewable energy in the EU. Brussels. (26.5.2004)
[14] Secretaría del Cambio Climático. Convención Marco de las Naciones Unidas sobre el Cambio Climático. "Los diez primeros años." Bonn (Alemania). (2004).
[15] J.I. Pérez Arriaga. Libro blanco sobre la refoma del marco regulatorio de la generación eléctrica en España. Madrid. (2005).
[16] P. Linares, F.J.Santos, I.G. Perez-Arriaga. Scenarios for the evolution of the Spanish electricity sector: is it on the right path towards sustainability?. Energy Policy 36 (11).4057–4068. (2011)
[17] Convenio Marco de las Naciones Unidas sobre el Cambio Climático. Instrumento de Ratificación del Protocolo de Kioto. Diciembre. (1997).
[18] Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Climate Change Impacts, Adaptation and Vulnerability. (2007)
[19] K. Blok. Enhanced policies for the improvement of electricity efficiencies, Energy Policy 33. 1635–1641. (2005)
[20] J.J. de Felipe Blanch., J. Xercavins y Valls. Posibles escenarios futuros mundiales de emisiones y absorciones de CO_2 y cumplimiento de los acuerdos de Kioto. UPC. (2002).
[21] IEA, 2004. World Energy Outlook 2004. OECD/IEA, Paris.
[22] IEA, 2005. World Energy Model 2005. OECD/IEA, Paris.
[23] IPCC special report on emissions scenarios. The multiregional approach for resource and industry allocation model (MARIA). http://www.grida.no/climate/ipcc/emis-

10% Online Discount
Use Code JR10

AUTOMATED DIAGNOSTICS AND ANALYTICS FOR BUILDINGS

Edited by Barney L. Capehart, Ph.D., and Michael R. Brambley, Ph.D.



With the widespread availability of high-speed, high capacity microprocessors and microcomputers with high-speed communication ability, and sophisticated energy analytics software, the technology to support deployment of automated diagnostics is now available, and the opportunity to apply automated fault detection and diagnostics to every system and piece of equipment in a facility, as well as for whole buildings, is imminent. The purpose of this book is to share information with a broad audience on the state of automated fault detection and diagnostics for buildings applications, the benefits of those applications, emerging diagnostic technology, examples of field deployments, the relationship to codes and standards, automated diagnostic tools presently available, guidance on how to use automated diagnostics, and related issues.

ISBN: 0-88173-732-1

8½ x 11, 615 pp., Illus.
Hardcover

$175
Order Code 0695

CONTENTS

BOOK ORDER FORM

① Complete quantity and amount due for each book you wish to order:

Quantity	Book Title	Order Code	Price	Amount Due
	Automated Diagnostics and Analytics for Buildings	**0695**	**$175.00**	
			Applicable Discount	
			Georgia Residents add 6% Sales Tax	
			Shipping $10 first book $4 each additional book	**10.00**
			TOTAL	

② Indicate shipping address: CODE: Journal 2014

NAME (Please print) ____ BUSINESS PHONE ____

SIGNATURE (Required to process order) ____ EMAIL ADDRESS ____

COMPANY ____

STREET ADDRESS ONLY (No P.O. Box) ____

CITY, STATE, ZIP ____

MEMBER DISCOUNTS—A 15% discount is allowed to AEE members (discounts cannot be combined).
☐ **AEE Member (Member No.____________)**

③ Select method of payment:
☐ **CHECK ENCLOSED**
☐ **CHARGE TO MY CREDIT CARD**
☐ *VISA* ☐ *MASTERCARD* ☐ *AMERICAN EXPRESS*

Make check payable in U.S. funds to:
AEE ENERGY BOOKS

CARD NO.

Expiration date ____ *Signature* ____

④ Send your order to:
AEE BOOKS
P.O. Box 1026
Lilburn, GA 30048

INTERNET ORDERING
www.aeecenter.org/books
(use discount code)

TO ORDER BY PHONE
Use your credit card and call:
(770) 925-9558

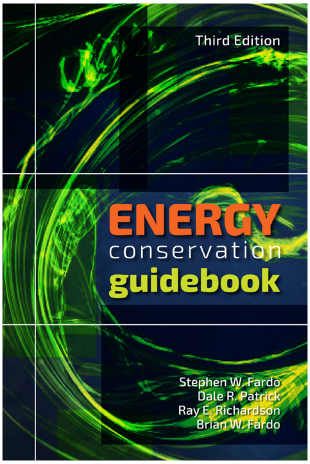
TO ORDER BY FAX
Complete and Fax to:
(770) 381-9865

INTERNATIONAL ORDERS
Must be prepaid in U.S. dollars and must include an additional charge of $10.00 per book plus 15% for shipping and handling by surface mail.

10% Online Discount
Use Code JR10

ENERGY CONSERVATION GUIDEBOOK, 3rd Edition

Stephen W. Fardo, Dale R. Patrick, Ray E. Richardson and Brian W. Fardo



Revised and edited, this new third edition reference covers the full scope of energy management techniques and applications for new and existing buildings, with emphasis on the "systems" approach to developing an effective overall energy management strategy. Foremost in the enhancements to the new edition is content that reflects the emphasis on conservation for green energy awareness. Building structural considerations are examined, such as heat loss and gain, windows, and insulation. A thorough discussion of heating and cooling systems basics is provided, along with energy management guidelines. Also covered are conservation measures which may be applied for lighting systems, water systems and electrical systems. Specific energy management technologies and their application are discussed in detail, including solar energy systems, energy management systems, and alternative energy technologies.

ISBN: 0-88173-716-X

6 x 9, 553 pp., Illus.
Hardcover

$125
Order Code 0699

CONTENTS

BOOK ORDER FORM

① Complete quantity and amount due for each book you wish to order:

Quantity	Book Title	Order Code	Price	Amount Due
	Energy Conservation Guidebook, 3rd Edition	**0699**	**$125.00**	
			Applicable Discount	
			Georgia Residents add 6% Sales Tax	
			Shipping $10 first book $4 each additional book	10.00
			TOTAL	

② Indicate shipping address: CODE: Journal 2014

NAME (Please print) BUSINESS PHONE

SIGNATURE (Required to process order) EMAIL ADDRESS

COMPANY

STREET ADDRESS ONLY (No P.O. Box)

CITY, STATE, ZIP

MEMBER DISCOUNTS—A 15% discount is allowed to AEE members (discounts cannot be combined).
☐ **AEE Member (Member No.____________________)**

③ Select method of payment:
☐ **CHECK ENCLOSED**
☐ **CHARGE TO MY CREDIT CARD**
☐ *VISA* ☐ *MASTERCARD* ☐ *AMERICAN EXPRESS*

Make check payable in U.S. funds to:
AEE ENERGY BOOKS

CARD NO.

Expiration date *Signature*

④ Send your order to:
AEE BOOKS
P.O. Box 1026
Lilburn, GA 30048

INTERNET ORDERING
www.aeecenter.org/books
(use discount code)

TO ORDER BY PHONE
Use your credit card and call:
(770) 925-9558

TO ORDER BY FAX
Complete and Fax to:
(770) 381-9865

INTERNATIONAL ORDERS
Must be prepaid in U.S. dollars and must include an additional charge of $10.00 per book plus 15% for shipping and handling by surface mail.

sion/153.htm. (2005)
[24] P. Frias, T. Gomez, P. Linares. Economic impact of 2020. Renewable energy scenarios on the Spanish electricity market. Inst. de Investig. Tecnol. Univ. Pontificia Comillas, Madrid, Spain Energy Market (EEM). 7th International Conference on the European. (2010)
[25] Y.P. Cai, G.H. Huang. An optimization-model-based interactive decision support system for regional energy management systems planning under uncertainty. Expert Systems with Applications 36. 3470–3482. (2009)
[26] Hatice Tekiner, W. David, Coit, A. Frank Felder. Multi-period multi-objective electricity generation expansion planning problem with Monte-Carlo simulation. EPSR_Electric Power Systems Research, Volume 80, Issue 12, December 2010, Pages 1394-1405
[27] L.M. Romeo, E. Calvo, Valero, et al. Electricity consumption and CO_2 capture potential in Spain. Energy 34. (2009). 1341–1350.
[28] J.B. Ang. CO_2 emissions, energy consumption, and output in France. Energy Policy 35. (2007) 4772–8.
[29] S. Simoes, J. Cleto, et al. Cost of energy and environmental policy in Portuguese CO2. abatement—scenario analysis to 2020. Energy Policy (36), (2008). 3598-3611.
[30] Peter Børre Eriksen. Economic and environmental dispatch of power/CHP production systems. Electric Power Systems Research, Volume 57, Issue 1, 31 (January 2001), Pages 33-39.
[31] Balance Energético 2006 y Perspectivas: El Sector del Petróleo. Dominique de Riberolles. Club Español de la Energía. Abril. (2007)
[32] A. Das, D. Rossetti di Valdalbero, M. Virdis. ACROPOLIS: an example of international collaboration in the field of energy modeling to support greenhouse gases mitigation policies. Energy Policy 35(2). (2007)
[33] E. Jadraque, J. Ordóñez, A. Espín. Development of an energy model for the residential sector: Electricity consumption in Andalusia, Spain. Energy and Buildings 43. 1315–1321. (2011)
[34] . International Conference on Renewable Energies and Power Quality Granada (Spain). March.2010. http://www.icrepq.com/icrepq'10/380-Verdejo.pdf
[35] Transition to Low-carbon Electricity by 2020 In Guangdong, China: Pathways and Costs. Yi Jingwei, Zhao Daiqing, Hu Xiulian, Cai Guotian Energy Engineering. Vol. 108, Iss. 6, 2011
[36] Spanish Office for Climate Change.(OECC) http://www.magrama.gob.es/
[37] International Energy Agency, "Key Statistics 2009-Reference Scenario 2030."
[38] Prospective Technological Evolution and Cost of Renewable Energy. Technical Study. Institute for diversification and energy saving. 2011.

ABOUT THE AUTHORS

M.A. Verdejo is a university professor and researcher in the department of electrical engineering at the Polytechnic School of Linares, University of Jaen, Spain. His research is based on energy models, distributed power generation technologies, and smart grids.

J. Moreno is a university professor and researcher in the department of electrical engineering at the Polytechnic School of Linares, University of Jaen, Spain.

They may be contacted at: mverdejo@ujaen.es.