UNIVERSIDAD PONTIFICIA COMILLAS

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

OFFICIAL MASTER'S DEGREE IN THE ELECTRIC POWER INDUSTRY

Master's Thesis

THE ECONOMICS OF ELECTRICITY GRID DEFECTION. A CASE STUDY

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Supervisor: Dr. Tomás Gómez San Román
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Madrid, August 2016

Official Master's Degree in the Electric Power Industry (MEPI)

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Summary

The electric power system is beginning to change thanks the rising of distributed energy resources (DERs) such as small fuel generators, electricity storage systems, small wind, combined heat and power plants and solar photovoltaic (PV). DER technological improvements and policy incentives are enabling the emergence of new grid configuration trends for the end-user.

The ability to store the energy produced by power generation systems is improving every day, thanks to innovations driven by the automotive industry on electric vehicles (EVs). Ramp up in production capacity for electric vehicles has driven down the cost of large-scale battery storage for power. Additionally, the cost of photovoltaic panels has fallen substantially in recent years. This is increasing the social and economic acceptance of these new grid configuration options.

This thesis focuses on two of these new customer usage trends: grid integrated and grid defection. Grid integrated enables customers to install PV systems that export power to the utility grid. In grid defection, consumers fully depend on their on-site power generation, using storage and a power management system to provide power to the home when needed. The methodology is implemented in the Distributed Energy Resources Customer Adoption Model (DER-CAM), and a case study is performed on solar PV and electricity storage system for rigorous assessment of the economic feasibility of leaving the grid on three representative Spain geographies (Córdoba, Guadalajara and Oviedo). Sensitivity analyses are carried out over important parameters such as DER capital costs, electricity export option to the grid, interest rate and rooftop PV available space. This thesis concludes and presents the findings of the analysis and provides a guide to future research.

Resumen

Los sistemas de energía eléctricos están empezando a cambiar gracias al auge de los sistemas de recursos energéticos distribuidos (DER), tales como pequeños generadores diesel, sistemas de almacenamiento de energía, plantas de cogeneración y plantas fotovoltaicas. Las mejoras tecnológicas en estos sistemas junto a unas políticas de incentivos están posibilitando la aparición de nuevas tendencias de configuraciones de red para los usuarios finales.

La habilidad para almacenar la energía producida por sistemas solares mejora cada día gracias a las innovaciones en la industria de la automoción sobre los vehículos eléctricos (EVs). El aumento en la capacidad de producción de vehículos eléctricos ha hecho bajar el coste en la producción a gran escala de baterías de almacenamiento de energía. Además, el coste de los paneles fotovoltaicos ha disminuido sustancialmente en los últimos años. Esto está incrementando la aceptación social y económica de estas nuevas opciones.

Esta tesis se centra en dos de estas nuevas tendencias: la integración con la red y estar totalmente aislado de la red eléctrica. La integración con la red permite a los consumidores la instalación de un sistema fotovoltaico y exportar los excesos de energía a la red de suministro. Aislados de la red eléctrica, los consumidores dependen completamente de la generación de energía in situ, usando un sistema de almacenamiento y de gestión de energía para suministrar energía a la casa cuando sea necesario. La metodología es implementada mediante un modelo en DER-CAM y se realiza un caso de estudio sobre un sistema fotovoltaico y de almacenamiento para una evaluación rigurosa de la viabilidad económica de abandonar la red en tres zonas geográficas representativas de España (Córdoba, Guadalajara y Oviedo). Un análisis de sensibilidad es llevado a cabo sobre importantes parámetros tales como los costes de capital de las tecnologías DERs, la posibilidad o no de exportar electricidad en la red, el tipo de interés y el área disponible para la instalación fotovoltaica. Por último, esta tesis concluye y presenta los resultados del análisis, introduciendo algunas posibles directrices para futuras investigaciones.

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This work of master thesis was a hard, complicated and full of obstacles enterprise. It has also been great support and assistance received, so they are many and deserved the acknowledgements I have to give to people that in one way or another they have had to do with the development of this work.

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Finally, express my gratitude to my classmates for the long hours of companies and shared moments during this time.

Abbreviations

CHP	Combined Heat and Power
CNMC	Comisión Nacional de los Mercados y la Competencia
CTC	Costes de Transición a la Competencia
DER	Distributed Energy Resources
DER-CAM	Distributed Energy Resources Customer Adoption Model
DES	Distributed Energy System
DG	Distributed Generation
DR	Demand Response
DS	Distributed Storage
EV	Electric Vehicles
GHI	Global Horizontal Irradiation
ICT	Information and Communication Technology
IEA	International Energy Agency
LBNL	Lawrence Berkeley National Laboratory
MILP	Mixed Integer Linear Programming
NREL	National Renewable Energy Laboratory
OECD	Organisation for Economic Co-operation and Development
OMEL	Operador del Mercado Ibérico de Energía
PV	Photovoltaics
REE	Red Eléctrica de España
T&D	Transmission and Distribution

Contents

List of Figures

List of Tables

1 Introduction

1.1 Background and Motivation

Different reports, media and institutions are already discussing that cost reduction on solar plus battery systems could enable total defection from the electric grid for certain energy users.

Solar power plus storage could reconfigure the organization and regulation of the electric power business over the coming decade ("HG Electric - Downgrading to Underweight The Solar Vortex : Credit Implications of Electric Grid Defection," 2017).

A national study from Australia concluded that such "independence" or "defection" scenarios are not currently cost competitive, but could become an economically feasible option in the period 2030-2050 (Future Grid Forum, 2013).

RMI's report, "The Economics of Grid Defection", assesses when and where distributed solar plus battery systems could reach economic parity with the electric grid, creating the possibility for defection of U.S. utility customers (Bronski et al., 2014).

A 2014 report from UBS bank commented, "Our view is that the 'we have done it like this for a century' value chain in developed electricity markets will be turned upside down within the next 10–20 years, driven by solar and batteries" (UBS, 2014). HSBC, in its report Energy Storage: Power to the People (Dickens, 2014), suggested that deployment of energy storage will accelerate the utility revenue decay trend already started by rooftop solar. And a Morgan Stanley report stated that, "Over time, many U.S. customers could partially or completely eliminate their usage of the power grid. We see the greatest potential for such disruption in the West, Southwest, and mid Atlantic"(Morgan Stanley Research, 2014).

Battery costs have declined rapidly, and it is expected a further decline up to 50% by 2020. Thanks to EV driven economies of scale, it is also expected the cost of stationary batteries to drop 50% by 2020 (UBS, 2014).

In our analysis, we will investigate whether under actual conditions a solar PV combined with a battery storage system becomes economically feasible, leading the customer to leave the grid.

In order to carry out a rigorous analysis of this phenomenon, we adopt the DER-CAM model which used GAMS to develop methods and tools for conducting an integrated assessment of DER systems. Understanding the full potential of decentralized energy systems requires advanced modeling and optimization methods. Here the Distributed Energy Resources Customer Adoption Model will help us. DER-CAM allows for quick yet comprehensive assessments of distributed energy resources (DER) and loads in microgrids, finding the optimal combination of generation and storage equipment to minimize energy costs and/or CO_2 emissions at a given site, while also considering strategies such as load-shifting and demand-response. DER-CAM can be used to generate an investment timeline over 20 years considering trends in both prices and technology performance, both for conventional and renewable technologies. It can also be used for dispatch of existing DER in day-ahead to week-ahead scheduling, based on load and weather forecasting. DER-CAM's strength derives from its flexibility, allowing the easy definition of additional constraints and parameters, such as net-zero energy requirements or financial incentives and subsidies for specific technologies (DER-CAM, 2016).

With the objective of finding the most economical decision for customers, three cases will be studied, Grid Supply, Grid Integrated and Grid Defection.

- Grid Supply. Is the traditional utility customer model with unidirectional electricity flow, from the utility grid to the end-user. System owners are connected directly to the grid and supply all of their electricity demand needs purchasing the electricity from the grid.

- Grid Integrated. System owners continue purchasing power from the grid, but reduce the amount purchased by using PV to supply a portion of their own electricity needs (and potentially get remuneration for any surplus generation that they may inject into the grid). Electricity flow can be bidirectional, from the utility grid to the end-user, and from the end-user to the utility grid.

- Grid defection. System owners could cut ties with the existing utility system in order to live "off the grid" and supply 100% of their own electricity needs with PV, storage, and other technologies, managing their own energy independently without the need for utilities and without enabling policies to support their decision. In an off grid system, consumers may have hours of non-supplied energy and therefore lower reliability than an interconnected system.

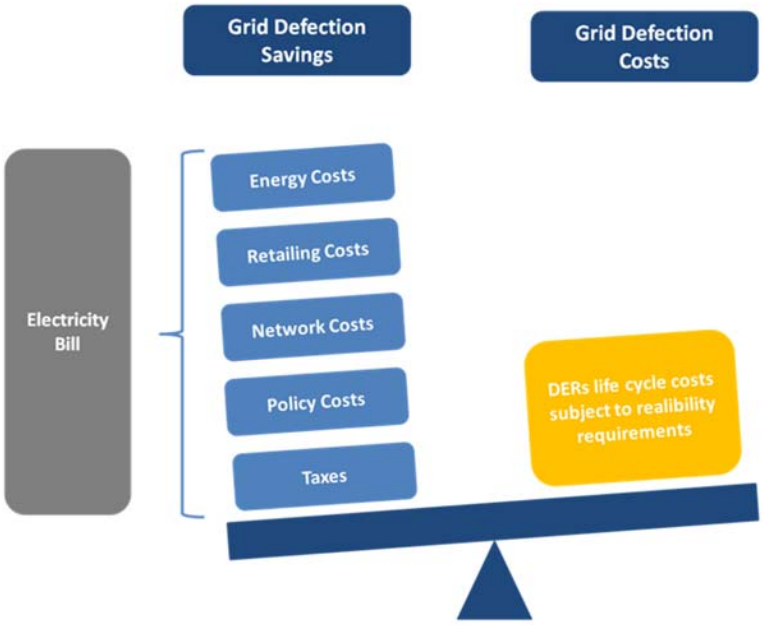
1.2 Objectives

Grid defection has become a popular term to describe customers adopting rooftop solar or other distributed generation resources and battery storage to disconnect from the electric grid and become electricity self-sufficient. Also new consumers not connected to the grid are considered as grid defection.

The aim of the thesis is to develop a quantitative analysis to assess the economic potential of DES component technologies for facilitating electricity grid defection. The chosen DES component technologies should be:

- Zero or very low carbon
- Commercially available
- Technologically advanced/mature
- Capable of full electricity grid independence (no electric connection required)

This thesis focuses on Solar plus Battery systems because these technologies are increasingly cost effective, relatively mature, commercially available today, and can operate fully independent from the grid.



Source: Grid & load defection: theory & evaluation. Utility of the Future Workshop (May 2016). Unpublished research

Figure 1-1: Grid defection: cost/benefit analysis from the consumer point of view

1.3 Structure

This report presents a quantitative analysis supporting cost effective customer defection from the grid. Chapter 1 introduces the falling costs and the improvements and performance of a range of distributed energy systems enabling a diversity of new customer-usage trends. This chapter also presents the motivation and the objectives for this thesis.

Chapter 2 provides a description of DER-CAM model which has been used to obtain the results and the methodology taken.

Chapter 3 performs a case study assessment of an emerging and heavily promoted DES: electricity storage and solar PV. This case study will cover representative residential grid integrated and grid defection options in different geographical regions of Spain.

Chapter 4 presents the results of this analysis from the case study performed.

Chapter 5 draws the main findings, concludes and identifies potential next steps.

2 Analytical Approach

Interconnected loads and distributed energy resources that can be controlled as a single entity, is appealing to increasing numbers of customers and communities, but figuring out how to design, develop, and finance nontraditional grid configurations in a right manner has proven challenging.

Techno economic models are designed to identify the optimal economic configuration of an emerging Grid Integrated and Grid Defection models. Doing that requires a technical component that allows for assessment of individual elements of the system, such as solar PV, energy storage, and others, in an integrated system. They also have an economic component that optimizes energy transactions between the customer system and the utility grid to meet a specified objective, such as minimizing cost. These components have been formulated into numerous techno economic models using a variety of optimization techniques.

In the published, academic literature two techno economic models dominate: the Hybrid Optimization Model for Multiple Energy Resources (HOMER) and DER-CAM. Here we review DER-CAM model.

2.1 DER-CAM Model Description

DER-CAM (Distributed Energy Resources Customer Adoption Model) is an investment and planning tool for DER adoption in microgrids or in individual customer sites. It is used to design and simulate DER systems. The Grid Integration Group at the Lawrence Berkeley National Laboratory (LBNL) has developed DER-CAM since 2000 and development is ongoing (DER-CAM, 2016).

DER-CAM is a mixed integer linear program written in the General Algebraic Modeling Software (GAMS) language, a modeling system for optimization problems. The model's objective function determines the lowest cost combination of available DERs to supply the electricity, heating, cooling, and natural gas loads of a utility customer. Upon investment, the system meets end-use consumption with energy purchases, on site generation, or energy recovered on site. DER-CAM first finds the optimal suite of distributed energy technologies that minimizes the total energy bill or emissions or combination thereof and second determines the optimal operating schedule over the entire year so as to meet that objective. The model provides comprehensive accounting of investment costs in conventional, combined heat and power, and renewable technologies, energy transactions between the microgrid or customer site and utility grid, fuel consumption, and carbon emissions.

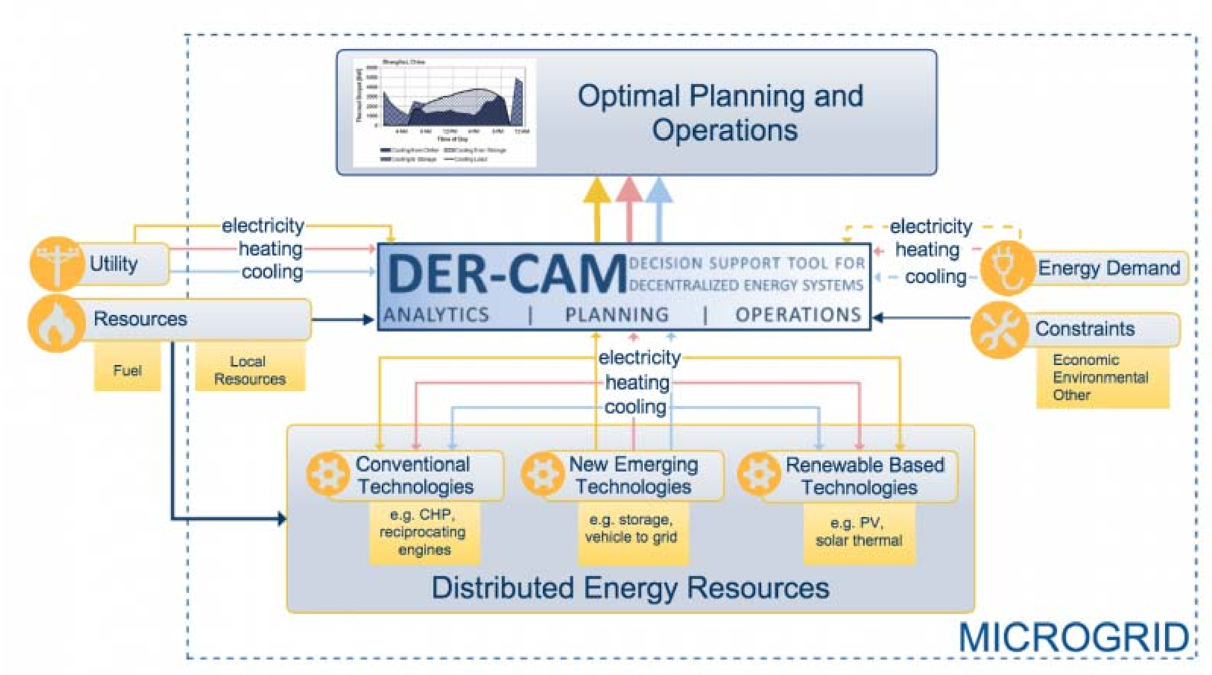


Figure 2-1: DER-CAM software tool

DER-CAM is technology neutral and thus can be adapted to a wide array of system settings, making it unwieldy to configure but particularly useful in studies such as the present one where many parameters need adjustment to real world conditions. The model considers the technical specifications and costs of several distributed technologies: (i) a suite of conventional generators such as micro turbines, gas turbines, and reciprocating engines of various capacities, with and without thermal recovery, and fueled with natural gas, diesel, or biodiesel; (ii) thermal units such as direct fired chillers, absorption chillers, solar thermal heating, heat pumps, and thermal storage; (iii) renewable technologies such as solar PV; and (iv) emerging technologies such as fuel cells, electric energy storage and EVs. The model considers load based capabilities as well, such as demand response and load scheduling.

DER-CAM exists in two primary branches: an investment and planning branch and an operations branch. The former determines the optimal suite and operation of distributed resources over one year, and the latter the optimal week ahead scheduling for installed energy resources.

Later developments by LBNL have, notably, included enhancements to allow analysis of particular case studies and scenarios. They include, for example, the addition of a carbon tax and its effect on microgrid CHP adoption, heat recovery, electric and thermal storage, power quality and reliability considerations, minimization of CO_2 emissions as a cost function objective, zero net energy building constraints, EVs, and building retrofits. Others using DER-CAM have also systematically analyzed parameters in DER-CAM that affect microgrid economics, for example tariff structures, energy storage, and climate zones. More recently, the modeling tool has been adapted to study the economic impact of EV integration in microgrids, the business case for ancillary service provision using electric storage in microgrids, and the economics of reactive power provision.

2.2 DER-CAM Model Formulation

DER-CAM's high level formulation is shown below:

Objective function:

Minimize total energy costs (or CO_2) such that:

- energy balance is preserved

  – energy supply (t) = energy demand (t)

- technologies operate within physical boundaries

  – power output (t) <= max output

- financial constrains are verified

  – max payback: savings obtained by the use of new DER must generate savings that repay investments within the max payback period

and specifically:

$\boldsymbol{MINIMIZE}$:

$\boldsymbol{Total\ energy\ costs}$: $electricity\ services\ purchase\ cost - electricity\ services\ sales\ revenue$

$+\ amortized\ DES\ investment\ cost + annual\ operation\ and\ depreciation\ costs$

$\boldsymbol{SUBJECT\ TO}$:

$\boldsymbol{Electricity\ balance}$: $electricity\ services\ purchased + electricity\ services\ generated$

$\geq electricity\ services\ demanded$

$\boldsymbol{Operational\ constraints}$: $generators, storage, and\ PV\ operate\ within\ performance\ limits$

$\boldsymbol{Investment\ constraints}$: $DES\ investments\ meet\ minimum\ payback\ requirements$

$\boldsymbol{Storage\ constraints}$: $electricity\ or\ heat\ stored\ is\ within\ storage\ parameter\ limits$

DER-CAM can be formulated to minimize the cost of providing electricity services to a consumer/ prosumer/ network user (conversely, maximize the profit of the network user), or, when modified, to maximize the profit of a given investment when selling services to the bulk power system. In either case, the model is formulated such that the DER is a price taker (Siddiqui et al., 2003); that is, in purchasing or selling services from or to the bulk power system, the DER does not change the price of those services. DER-CAM is formulated as a mixed integer linear program (MILP), programmed in GAMS, and solved using CPLEX (GAMS, n.d.). At their most simple level, MILPs are formulated as follows:

$$Min\ c^T x + d^T y$$
$$s.t.\ Ax + By = b$$
$$x \in \mathbb{R}_+^{n_x}, \mathbb{Z}_+^{n_y}$$

Where c is the vector of cost coefficients for the continuous decision variable x, and d is the vector of cost coefficients for the integer variable y (that is, y can only take on integer values such as 1, 2, 3, etc.). A is a matrix of coefficients for constraints on x, and B is a matrix of coefficients for constraints on y. b is the vector of coefficients corresponding to A and B. Finally, x can be any positive real number, and y can be any positive real integer number.

The inputs, the output and the assumptions of the model are described in(Burger, 2015) and presented below.

Key inputs into the model are:

1. Customer's end use load profiles (typically for space heat, hot water, gas only, cooling, and electricity only).
2. Customer's default electricity tariff, natural gas prices, and other relevant price data.
3. Capital, operating and maintenance (O&M), and fuel costs of the various available technologies, together with the interest rate on customer investment.
4. Basic physical characteristics of alternative generating, heat recovery and cooling technologies, including the thermal electric ratio that determines how much residual heat is available as a function of generator electric output.

Outputs to be determined by the optimization model are:

1. Capacities of DG and CHP technology or combination of technologies to be installed.
2. When and how much of the capacity installed will be running.
3. Total cost of supplying the electric and heat loads.

The key assumptions are:

1. Customer decisions are made based only on direct economic criteria. In other words, the only possible benefit is a reduction in the customer's electricity bill.
2. No deterioration in output or efficiency during the lifetime of the equipment is considered. Furthermore, start up and other ramping constraints are not included.
3. Reliability and power quality benefits, as well as economies of scale in O&M costs for multiple units of the same technology are not directly taken into account.
4. Possible reliability or power quality improvements accruing to customers are not considered.
5. Customer's end use load profiles only consider electricity.
6. No hours without power supply are allowed (i.e. demand always need to be met).

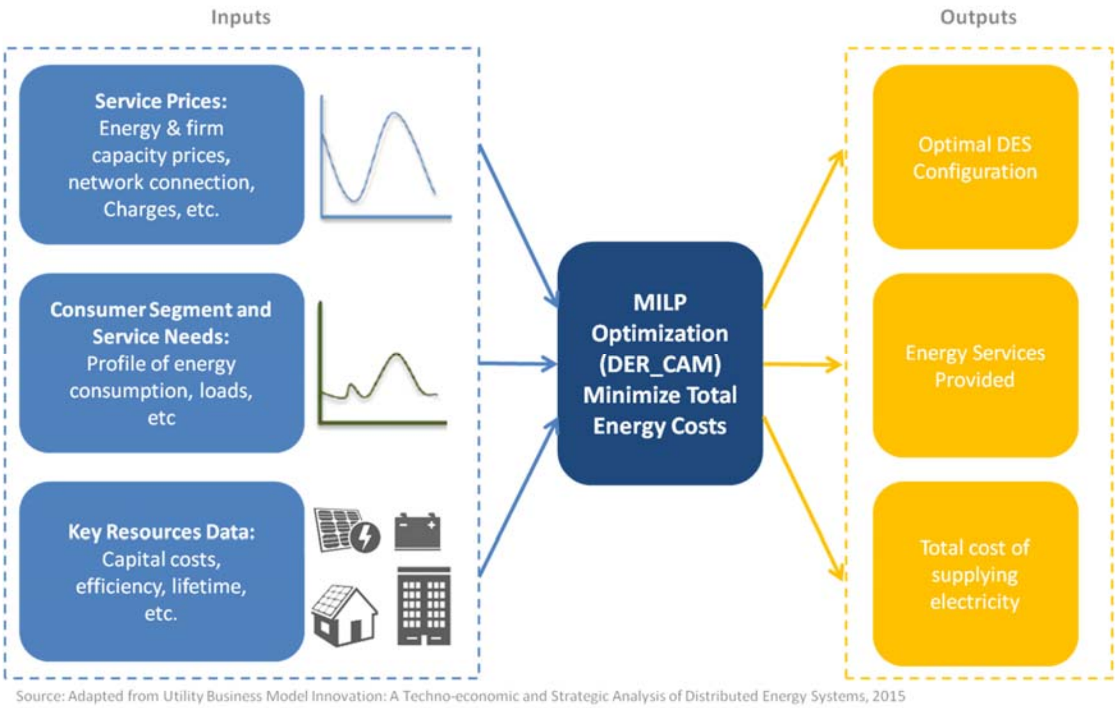


Figure 2-2: DER-CAM Inputs and Outputs

3 Case Study

3.1 Case study

Case study goal is to carry out an economic analysis of leaving the grid from the end user point of view in three configurations, Grid Supply, Grid Integrated (Grid Supply + DER) and Grid Defection, see below the assessment framework (Koirala et al., 2016), in three different geographical locations in Spain, Córdoba, Guadalajara and Oviedo.

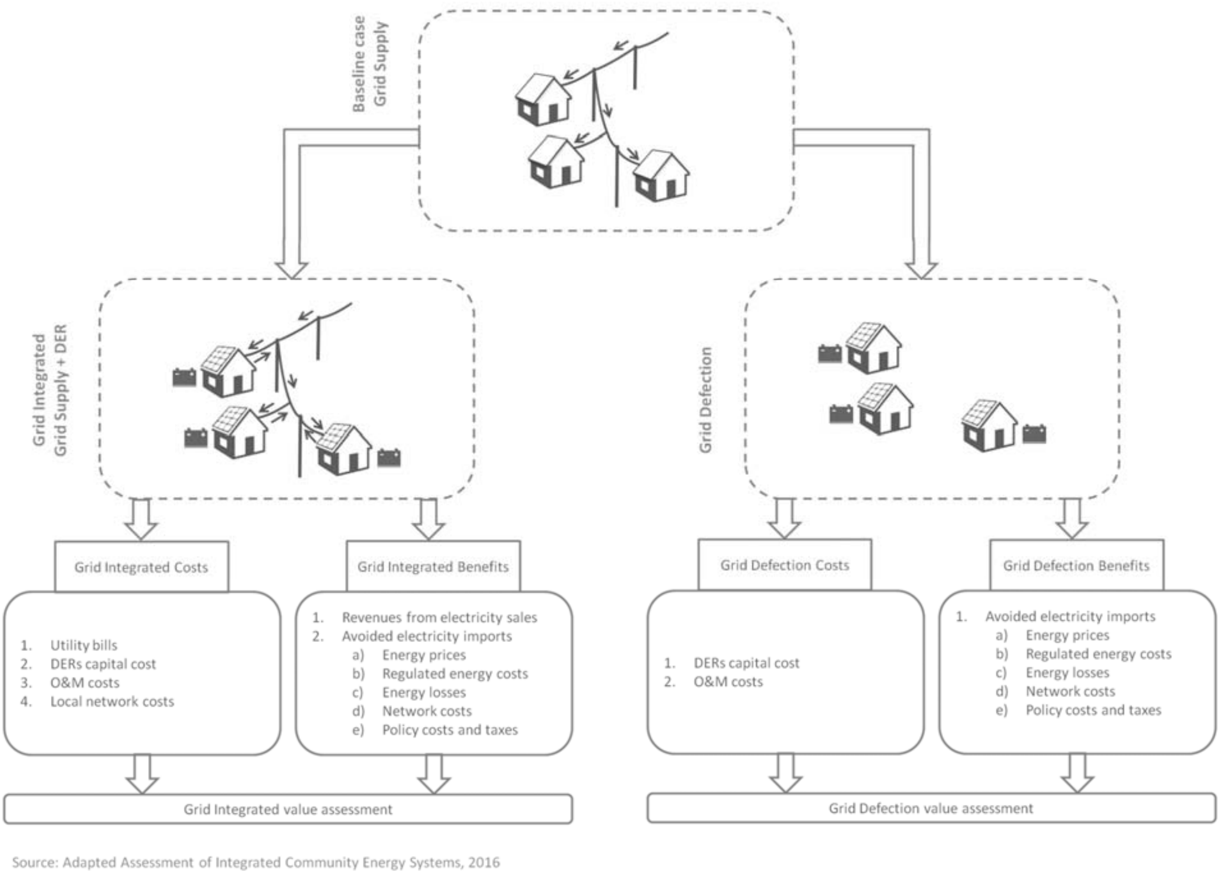


Figure 3-1: Assessment Framework

The feasibility of renewable technologies is critically dependent on the location's richness in terms of energy resources (e.g., GHI for PV systems and wind speed for wind turbines).

Figure 3-2 shows graphically the distribution of global horizontal irradiation (GHI) in Spain (lower). It shows how significantly the annual GHI varies around the world, from below 0,7

MWh/m² year to above 2,7 MWh/m² year. GHI spans from high in the south to low values in the northwest. This feature enables us comfortably to select cities from within Spain for sensitivity analysis of the impact of location on DG performance.

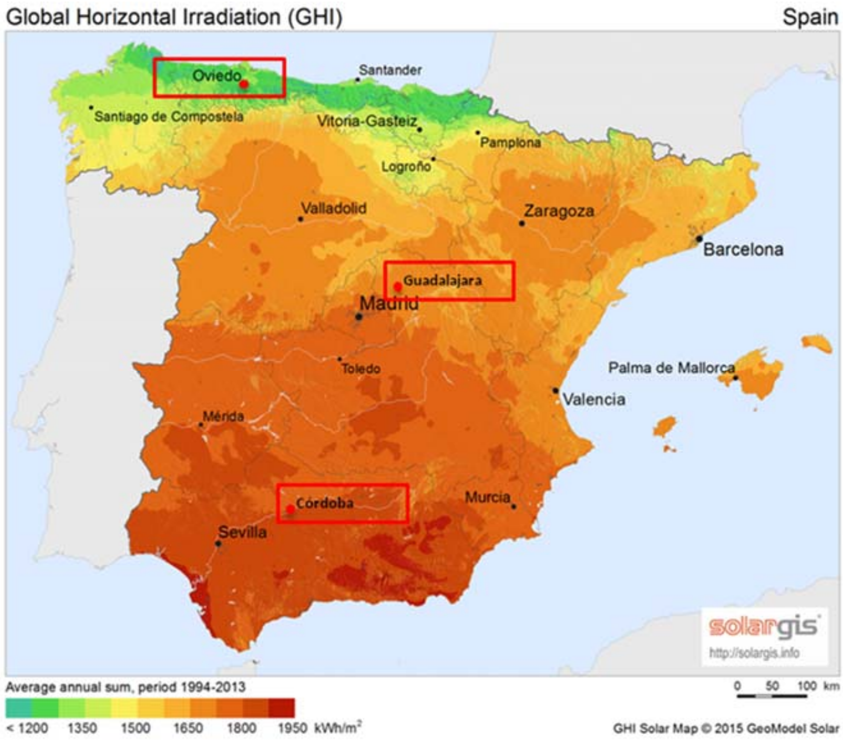


Figure 3-2: Graphical distribution of global horizontal irradiation GHI around the world (top) and in Spain (lower)

We select three locations with different GHI. The first is Córdoba (latitude 37,79 and average annual GHI 5,2 kWh/m²), the second is Guadalajara (latitude 40,57 and average annual GHI 4,8 kWh/m²), and the third, with the highest irradiation, is Oviedo (latitude 43,40 and average annual GHI 3,8 kWh/m²). The GHI profiles are illustrated in Figure 3-3.

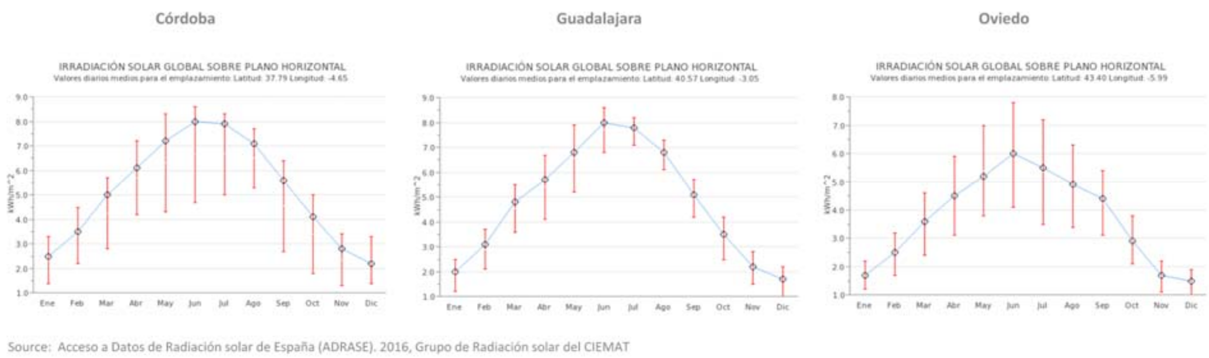


Figure 3-3: Average GHI (10 years) of Córdoba, Guadalajara, and Oviedo

The feasibility of renewable technologies also depends on the load profile. We select one house in each of the locations. The annual load profiles for the three houses are given in Figure 3-4. House Córdoba has consumed 3,79 MWh of electricity during the base year, house in Guadalajara has consumed 5,39 MWh and the consumption of house in Oviedo is 1,38 MWh.

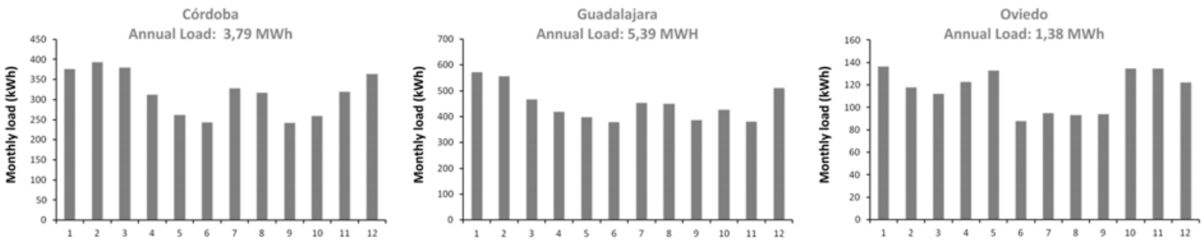


Figure 3-4: Load profile for the house in Córdoba, Guadalajara and Oviedo

The three houses have no similar annual energy consumption. Load pattern has a significant impact on PV plus Battery feasibility, especially in regions with low medium GHI. We know that PV output depends on the sun's location; it increases in summer and reduces in winter. We would expect, therefore, that a PV system would be more economical for a house with a summer peak.

A sensitivity analysis is the computation of the effect of changes in input values or assumptions on the outputs. In order to assess the impact of a change in some of these techno economic parameters on the grid integrated systems, and to draw important conclusions, a one way sensitivity analysis is conducted for each location in the following chapter.

Of the many parameters in the model, the following are used to conduct the sensitivity study:

- Maximum space available for PV
- Export. This helps assess the impact for the customers installing DER systems that do not export electricity to the utility grid. These systems can incorporate the use of energy storage devices, like batteries. All power produced by the customer's system will need to be used or stored to be used by the customer at a later time.
- DER capital cost. Here, we investigate the impact of a probable decline in technology costs on the DER systems.
- Interest rate. This helps determine the optimal and cheapest system configurations. In this case, the system under consideration involves Solar PV plus Batteries, technology with high upfront costs and low operational costs.

4 Results

4.1 Córdoba

A house in Córdoba has consumed within one year about 3,79 MWh of electricity. The consumer's load profile during the base year is illustrated in Figure 3-4 [Córdoba]. The data is obtained from the smart-meter measurements (Endesa Distribución, 2015).

Data for Spanish hourly wholesale and retail electricity prices for 2015 are obtained from (ESIOS, 'Mercados y precios,' 2015). The retail electricity price includes wholesale price and the regulated costs such as surcharges and taxes. A contracted capacity charge mainly covers network costs.

4.1.1 Baseline case – Grid Supply

Under this electricity pricing scheme, the house has spent 713,301 € for its electricity bill over one year. Table 4-1 presents the total cost for baseline case.

Table 4-1: Córdoba total costs in grid supply configuration

Total electricity consumption (kWh)	**3.794,107**
Total energy costs (€)	**713,301**
Total electricity costs (€)	**713,301**
Energy costs	**144,091**
Network costs	**120,020**
Policy costs	**265,587**
Taxes	**183,603**
Average energy cost (€/kWh)	**0,188**

Figure 4-1 represents the electricity cost components.

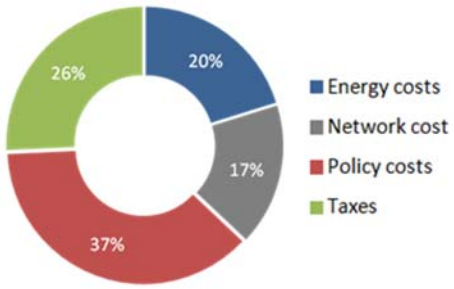


Figure 4-1: Córdoba electricity cost components (%) in grid supply configuration

The present tariff structure in Spanish Electricity System is based on the Royal-Decree 1432/2002. The costs components included in the tariff structure of the regulated and liberalized markets are defined as follows:

- Generation Activity Costs. These costs include mainly Ordinary Generation and Special Regime Generation.

- Diversification and System Security Costs. These costs include the Moratoria nuclear, cost associated with the compensation for the cancelations or anticipated maturity of nuclear installation's projects in the 80s, and Special compensation to distribution companies for interruptions, purchase on special regime and losses.

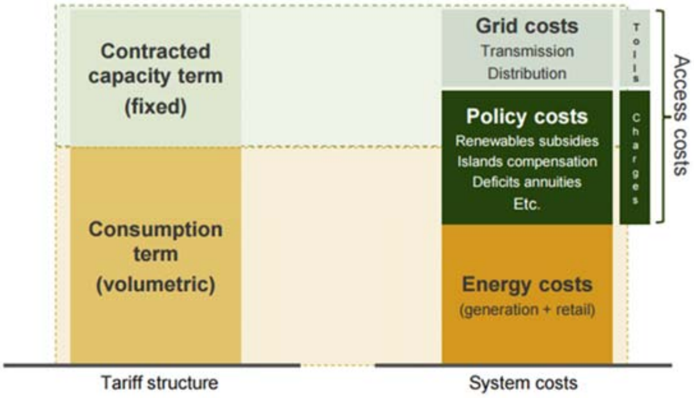
- Tariff Deficit and Extra-peninsular Costs. Deviations on production cost.

- Permanent System Costs. Includes the CNMC, remuneration of the regulator; Market Operator, remuneration of the Spot Market Operator (OMEL); System Operator, remuneration of the REE; Extra-peninsular compensation, compensation for having generation and operation costs higher than the proceeds coming from the tariff; and CTCs, incentive for the consumption of national coal and for the remuneration of its stock.

- Transmission Costs. Remuneration is based individually for each company and includes the remuneration of the operating installations and the remuneration of the new ones.

- Distribution Costs. Remuneration depends on investment costs, operating and maintenance costs, volume of distributed electricity, type of distribution grid and of the quality of service and losses reduction incentives.

- Regulated Supply Costs. Includes costs with the commercial activity developed by the distribution companies, namely client service, meter reading, invoicing, etc.



Source: Electricity tariff structure – Spanish experience. Network investment and regulation. IEA, 2015

Figure 4-2: Spanish tariff structure and system costs

Table below presents the Spanish energy tariffs component values considered in this study:

Table 4-2: Spanish energy tariff components

Energy costs	Wholesale energy price	OMIE 2015
	Balancing cost (€/kWh)	0,07
	Losses coefficient (%)	14,8
Policy costs	Policy component (€/kWh)	0,07
Taxes	Electricity taxes autonomous communities (%)	6
	VAT (%)	21
Grid costs	Peak demand charge (€/kW/month)	4,65

Figure 4-3 illustrates a typical May week daily profile of the house's electricity supply obtained from the program results. The house receives the total electricity consumption directly from the utility grid.

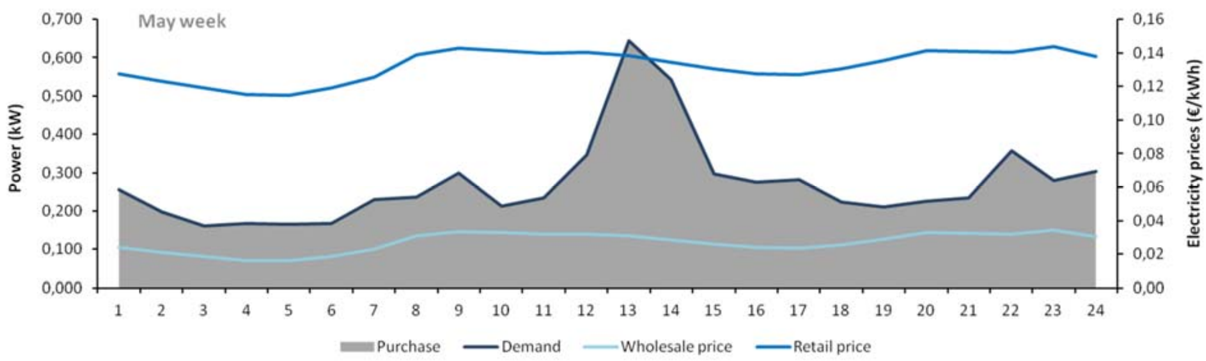


Figure 4-3: Energy balance for May week day in grid supply configuration

The house has an initial contracted capacity of 3,319 kW.

4.1.2 Grid Integrated

In this grid configuration, we are interested to investigate the economics of solar PV systems to supply the electricity demand. The PV system can generate electricity to use directly or to export in the utility grid.

The monthly average solar irradiance and temperature data for Córdoba are obtained from (Energy Plus, 'Weather Data by Region | Energy Plus,' 2016). See Apendix A and Apendix B.

Table 4-3 presents the techno-economic data of household level DERs used in this analysis.

Table 4-3: Solar PV techno-economic data of household

DERs	Capital cost	Fixed O&M Cost	Interest rate	Maximun payback period	Lifetime
Solar PV	**1280 €/kW**	**0,5 €/kW/year**	**5 %**	**10 years**	**30 years**

Table 4-4 presents the total cost for Grid Integrated case.

Table 4-4: Córdoba total costs in grid integrated configuration

Total utility electricity consumption (kWh)	**1.813,884**
Total electricity self-consumption (kWh)	**1.983,049**
Total energy costs (€)	**453,086**

Total electricity costs (€)	**371,233**
Energy costs	**59,772**
Network costs	**88,937**
Policy costs	**126,971**
Taxes	**95,554**
DER costs (€)	**453,737**
Revenues from Electricity sales (€)	**371,885**
Average energy cost (€/kWh)	**0,119**

Under this grid scheme, the house receives 1813,884 kWh (48%) of electricity directly from the grid. The remaining demand is satisfied by the PV system, 1983,049 (52%). The total energy cost is 453,086 €, the electricity costs are 371,233 € and the revenues from the electricity sales are 371,885 €. The total energy cost value is the sum of the total electricity cost plus DER cost minus the revenues from the electricity sales.

In this case, the contracted capacity is reduced to 2,192 kW, explaining the reduction in network cost from 120,020 € in baseline case to 88,937 €. In the grid connected case, the model used does not consider the increase of contracted capacity to export PV generation.

Figure 4-4 and Figure 4-5 present the energy balance for this case in two different months to investigate the impact of seasonality and load profiles. In May the PV output is mainly allocated for local use, providing for the 100 % local load between 7:00 am and 8:00 pm. There is a high surplus PV generation which is dispatched to the grid.

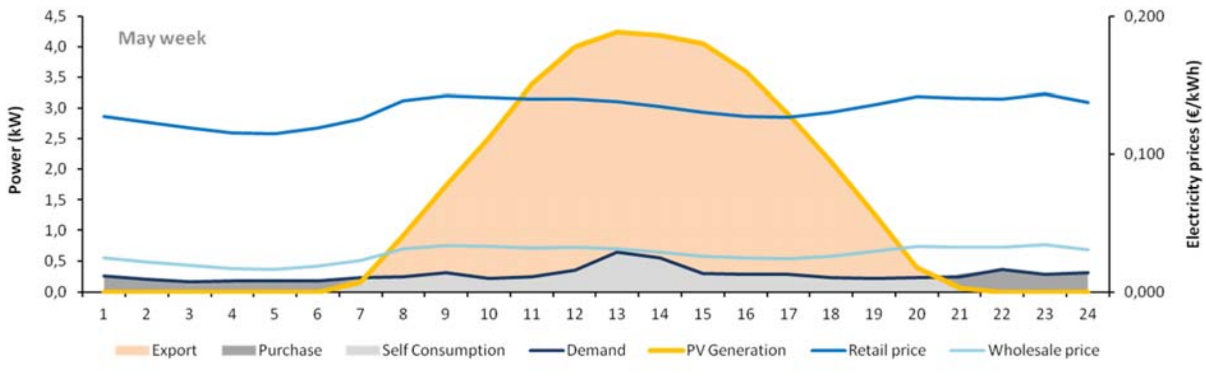


Figure 4-4: Córdoba Energy balance for May week day in grid integrated configuration

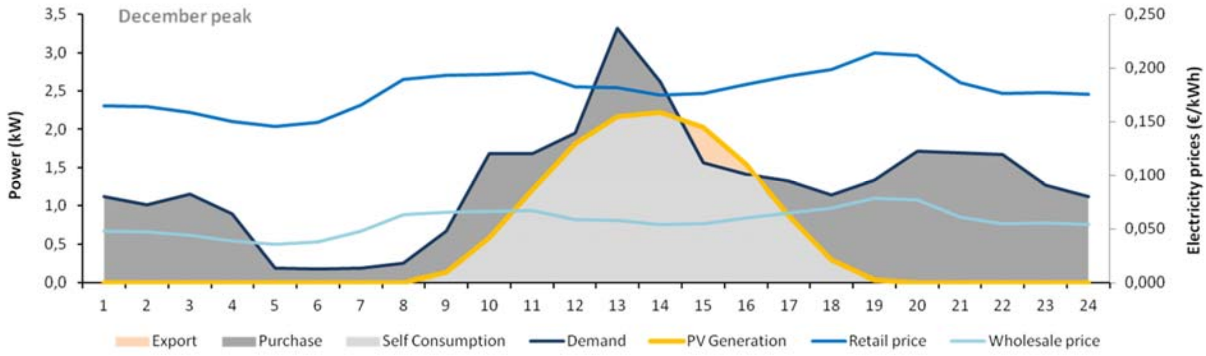


Figure 4-5: Córdoba Energy balance for December peak day in grid integrated configuration

In December PV output is not sufficient to meet all the local demand during PV generation hours. Besides, there is a significant reduction of electricity injected to the grid.

Figures below present the annual electricity consumption (Figure 4-6) and the annual PV generation (Figure 4-7).

Total Electricity Consumption (Kwh)	3.796,933
Electricity Purchase	1.813,884
Electricity self-consumption	1.983,049

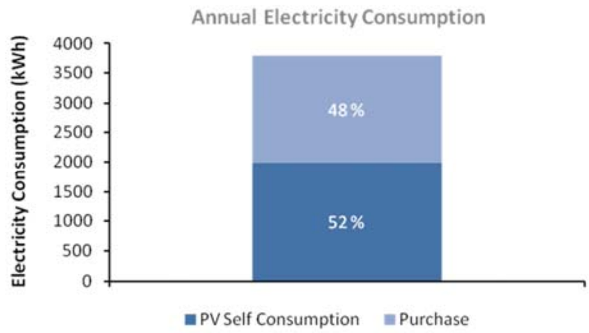


Figure 4-6: Córdoba annual electricity consumption in grid integrated configuration

PV Generation (Kwh)	9.670,490
Electricity Export	7.687,441
Electricity self-consumption	1.983,049

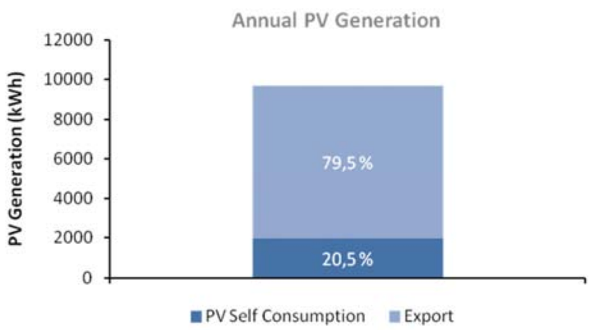


Figure 4-7: Córdoba annual PV generation in grid integrated configuration

In this case, the cost-optimal PV system size requires a PV capacity of 5,337 kW and a PV area of 33,357 m^2.

DER-CAM optimization techniques find both, the combination of equipment and its operation over a typical year that minimizes the site's total energy bill or CO2 emissions, typically for electricity plus O&M cost and fuel purchases, as well as amortized equipment purchases (Stadler et al., 2014).

The dispatch and the sizing of technologies are optimized simultaneously. DER-CAM finds the best size to supply the local load. However, as the size increases, the installation cost per unit size decreases and in the case of grid integrated, this moves the household into a new paradigm in which it becomes an energy generator and sell energy to the grid at wholesale market rates. It becomes economical to generate and sell electricity to the grid.

4.1.3 Grid Defection

In this scenario we perform an economic study of grid defection through a PV plus battery system. We will look at the potential use of PV and battery storage as a stand-alone system to supply a customer's demand. More specifically, we will investigate whether under actual conditions it becomes economically feasible for the customer to leave the grid.

The description of techno-economic data (the same for three locations) are the following:

Table 4-5: PV-battery system techno-economic data of household

DERs	Capital cost	Fixed O&M Cost	Interest rate	Maximun payback period	Lifetime
Solar PV	**1280 €/kW**	**0,5 €/kW/year**	**5 %**	**10 years**	**30 years**
Storage	**300 €/kW**	**0,108 €/kW/year**	**5 %**	**10 years**	**10 years**

Total costs are illustrated in table below.

Table 4-6: Córdoba total costs in grid defection configuration

Total utility electricity consumption (kWh)	**0,000**
Total electricity self-consumption (kWh)	**3.925,331**
Total energy costs (€)	**4.584,741**

Total purchased electricity costs (€)	**0,000**
DER costs (€)	**4.584,741**
Average energy cost (€/kWh)	**1,167**

The total energy cost is 4584,741 €, approx. 10 times higher than grid integrated option.

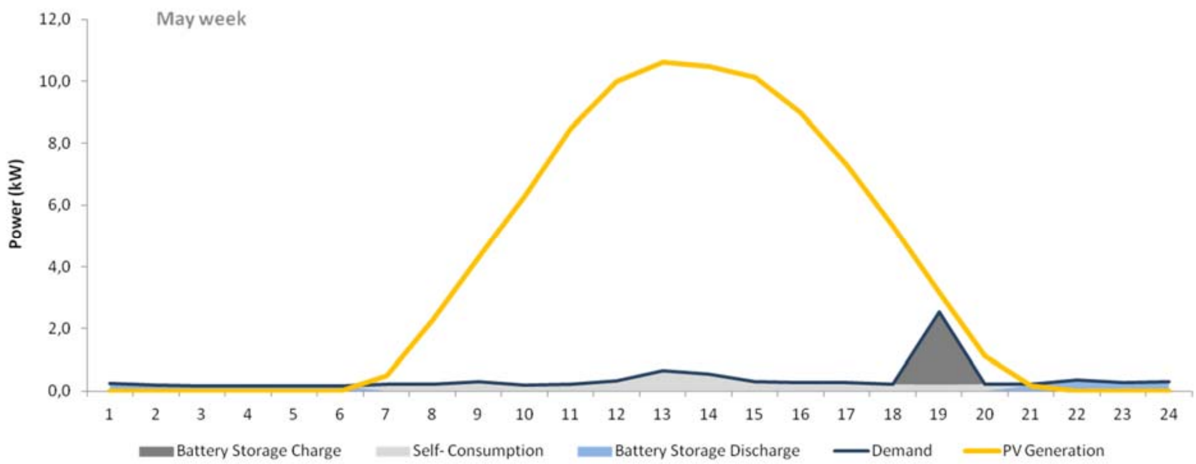


Figure 4-8: Córdoba Energy balance for May week day for grid defection option

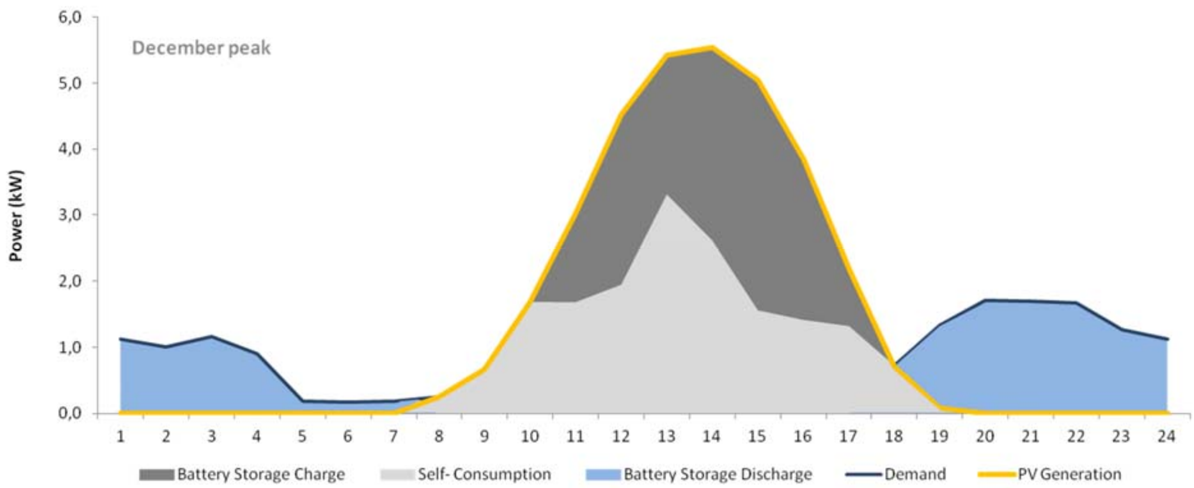


Figure 4-9: Córdoba Energy balance for December peak day for grid defection option

In both months, the total demand is satisfied by the PV-battery system and there is no utility electricity consumption. In December there is no non-used energy and PV generation is used to charge the battery and supply the demand.

PV Generation (Kwh)	**24.151,391**
Annual Nonused	**20.226,060**
Annual self-consumption	**3.925,331**

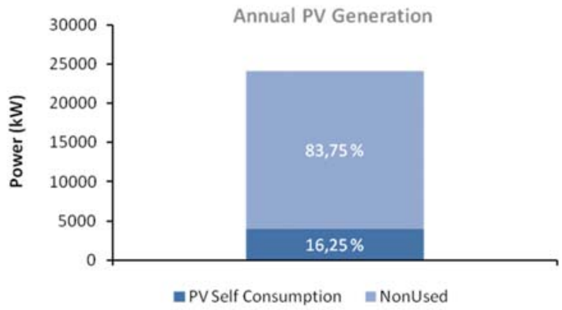


Figure 4-10: Córdoba annual PV generation in grid defection configuration

Only a 16,25 % of total PV generation is necessary for local demand; there is a significant 83,75 % of non-used energy.

For the PV plus battery system, the cost optimal size requires a PV capacity of 13,333 kW, a battery capacity of 83,811 kWh and a PV area of 83,332 m^2.

4.1.4 Córdoba Comparative Assessment

Figure 4-11 and Figure 4-12 presents a comparison of results for the grid configurations evaluated.

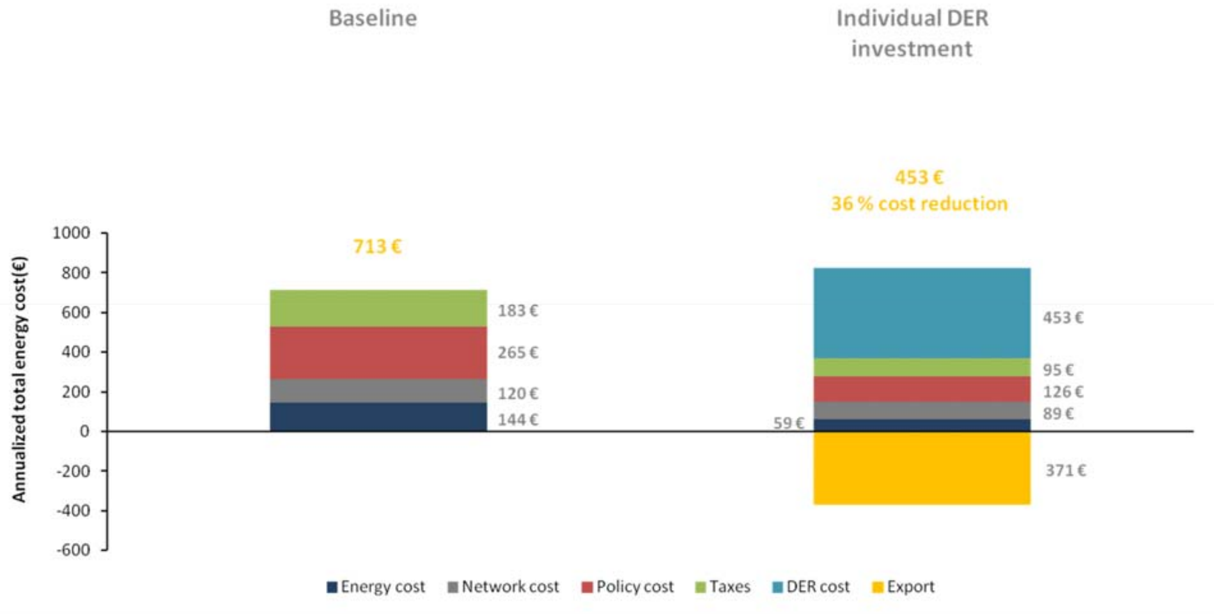


Figure 4-11: Córdoba grid connected options comparative cost

The total energy cost for Individual DER investment is 453 €, there is a 36 % cost reduction respect Baseline. The revenues from the electricity sales to the utility grid are 371 €. Average baseline energy cost is 0,188 €/kWh and average grid integrated energy cost is 0,119 €/kWh. Main savings are due to the reduction (59%) on energy cost by installing a PV system.

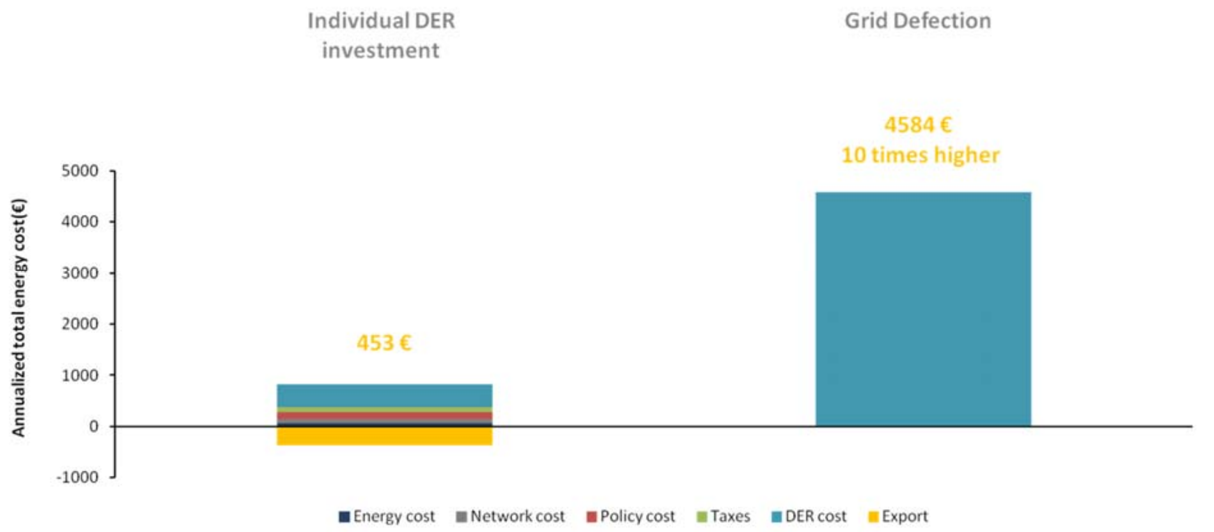


Figure 4-12: Córdoba grid integrated and grid defection comparative cost

It is evident that the best scenario for customers occurs for houses connected to the utility grid with a PV system. The high cost obtained for the case of grid defection, shows this option is not economically rational.

4.2 Guadalajara

In Guadalajara the consumption during one year was about 5,39 MWh of electricity. The consumer's load profile during the base year is illustrated in Figure 3-4 [Guadalajara]. The data is obtained from the smart-meter measurements (Iberdrola, 2015).

4.2.1 Baseline case – Grid Supply

In the baseline case, the house has spent 1010,141 € for its electricity bill over one year. Table 4-7 presents the total cost for baseline case.

Table 4-7: Guadalajara total costs in grid supply configuration

Total electricity consumption (kWh)	**5.398,643**
Total energy costs (€)	**1.010,141**
Total electricity costs (€)	**1.010,141**
Energy costs	**210,249**
Network costs	**161,978**
Policy costs	**377,905**
Taxes	**260,009**
Average energy cost (€/kWh)	**0,187**

Figure 4-13 represents the electricity cost components.

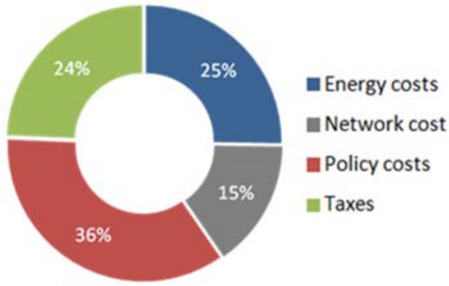


Figure 4-13: Guadalajara electricity cost components (%) in grid supply configuration

Figure 4-14 illustrates a typical May week daily profile of the house in Guadalajara. The house receives the total electricity consumption directly from the utility grid. The contracted capacity is 3,735 kW.

Figure 4-14: Guadalajara Energy balance for May week day in grid supply configuration

4.2.2 Grid Integrated

The monthly average solar irradiance and temperature data for Guadalajara are obtained from (Energy Plus, 'Weather Data by Region | Energy Plus,' 2016). See Apendix A and Apendix B.

The techno economic data of household level DERs used for this location is the same that one for Córdoba (see Table 4-5).

Table 4-8 presents the total cost for Grid Integrated case in Guadalajara.

Table 4-8: Guadalajara total costs in grid integrated configuration

Total utility electricity consumption (kWh)	**2.319,075**
Total electricity self-consumption (kWh)	**3.079,568**
Total energy costs (€)	**694,545**
Total electricity costs (€)	**474,530**
Energy costs	**81,751**
Network costs	**108,301**
Policy costs	**162,335**
Taxes	**122,143**
DER costs (€)	**550,696**
Revenues from Electricity sales (€)	**330,681**
Average energy cost (€/kWh)	**0,128**

Under this grid scheme, the house receives 2319,075 kWh (43 %) of electricity directly from the grid. The remaining demand is satisfied by the PV system, 3079,568 (57 %). The total energy cost is 694,545 €, the electricity costs are 470,530 € and the revenues from the electricity sales are 330,681 €. In this option, the contracted capacity is 2,822 kW.

Figure 4-15 and Figure 4-16 show the energy balance for grid integrated option for a typical May week day and December peak day, respectively. In May the PV output is mainly allocated for local use, providing for the 100 % local load between 7:00am and 8:00pm. The surplus PV generation is export to the grid. In December PV output is not sufficient to meet all the local demand during PV generation hours and there is no electricity injected to the grid.

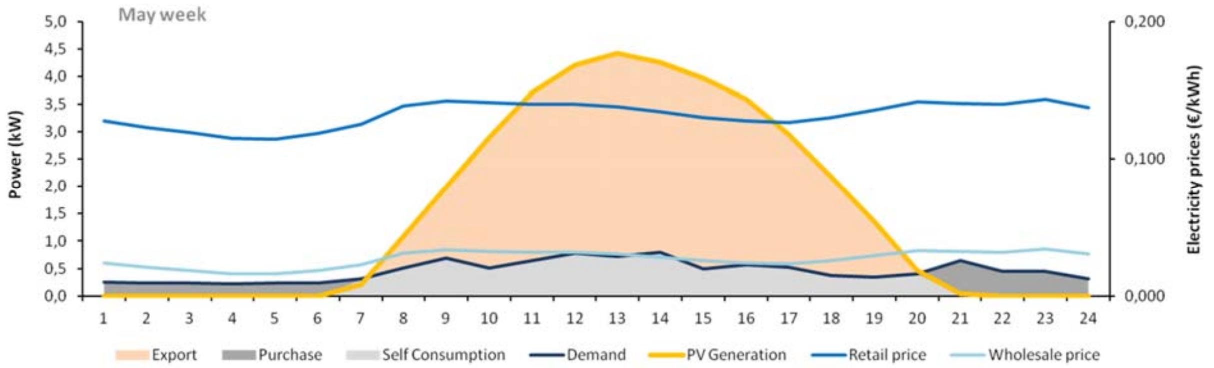


Figure 4-15: Guadalajara Energy balance for May week day in grid integrated configuration

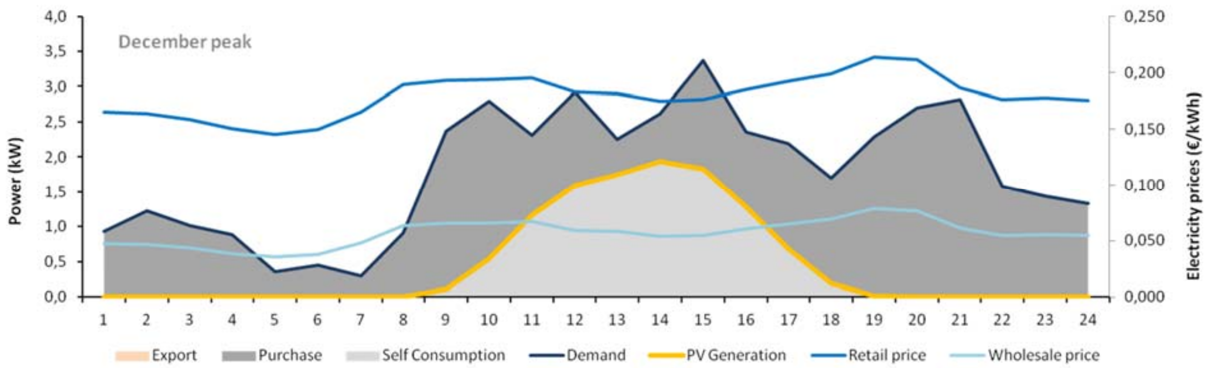


Figure 4-16: Guadalajara Energy balance for December peak day in grid integrated configuration

Figures below present the annual electricity consumption (Figure 4-17) and the annual PV generation (Figure 4-18).

Total Electricity Consumption (Kwh)	**5.398,643**
Electricity Purchase	**2.319,075**
Electricity self-consumption	**3.079,568**

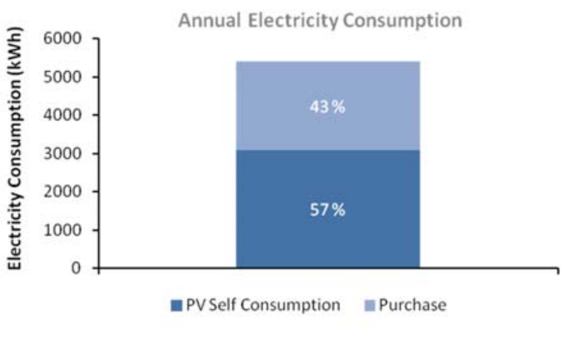


Figure 4-17: Guadalajara annual electricity consumption in grid integrated configuration

PV Generation (Kwh)	10.070,399
Electricity Export	6.990,831
Electricity self-consumption	3.079,568

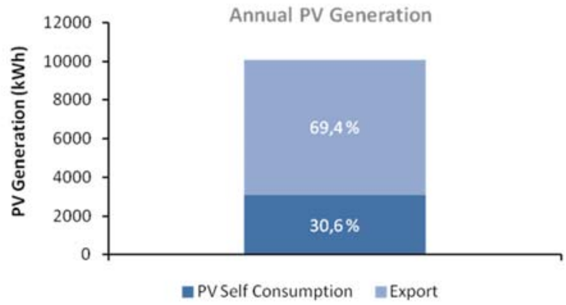


Figure 4-18: Guadalajara annual PV generation in grid integrated configuration

In Guadalajara, the cost-optimal PV system size requires a PV capacity of 6,477 kW and a PV area of 40,485 m^2.

4.2.3 Grid Defection

Total costs for Guadalajara are illustrated in table below.

Table 4-9: Guadalajara total costs in grid defection configuration

Total utility electricity consumption (kWh)	**0,000**
Total electricity self-consumption (kWh)	**5.552,236**
Total energy costs (€)	**6.899,215**
Total purchased electricity costs (€)	**0,000**
DER costs (€)	**6.899,215**
Average energy cost (€/kWh)	**1,242**

In this case, the total demand is satisfied by the PV-battery system and there is no utility electricity consumption. The total energy cost is 6899,215 €, approx. 10 times higher than grid integrated option.

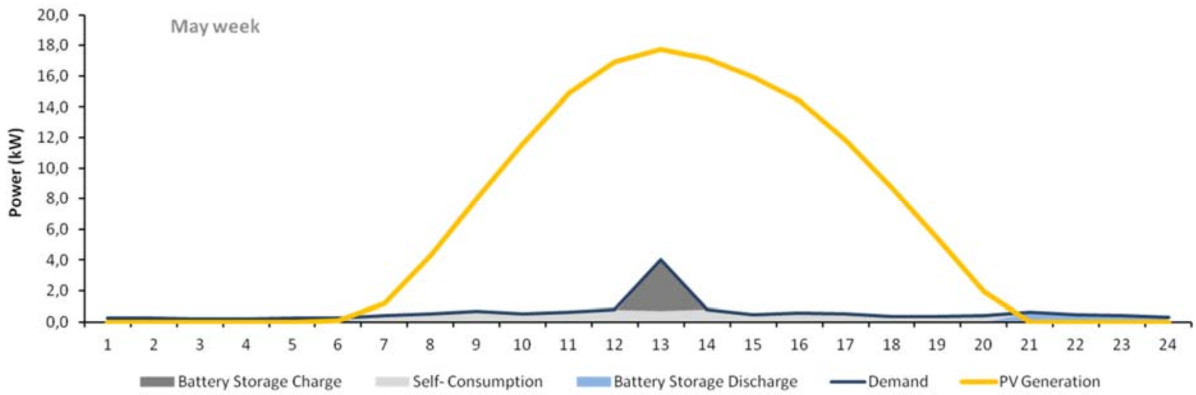


Figure 4-19: Guadalajara Energy balance for May week day for grid defection option

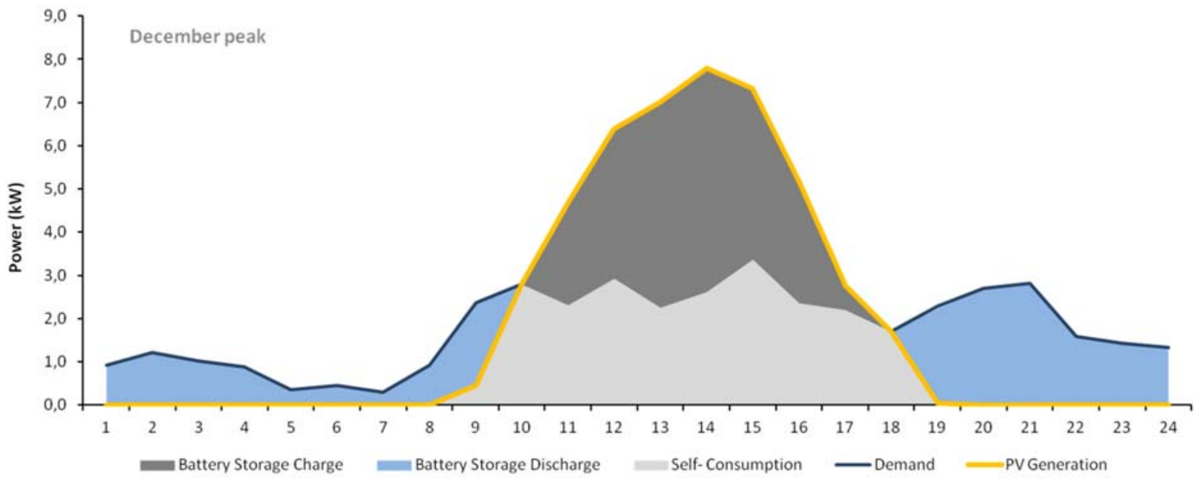


Figure 4-20: Guadalajara Energy balance for December peak day for grid defection option

Likewise, in both months, the total demand is satisfied by the PV-battery system and there is no utility electricity consumption. It is significant the amount of non-used energy in May week day compared with December peak day, in which there is no non-used energy and PV generation is used to charge the battery.

PV Generation (Kwh)	40.445,228
Annual Nonused	34.892,992
Annual self-consumption	5.552,236

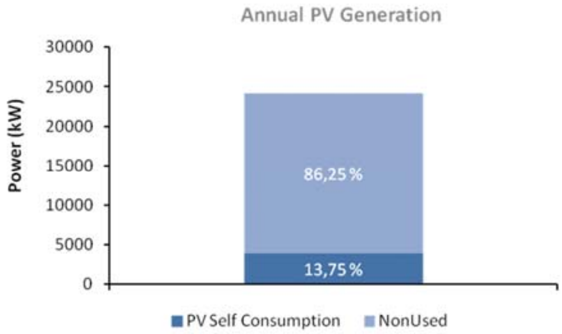


Figure 4-21: Guadalajara annual PV generation in grid defection configuration

Only a 13,75 % of total PV generation is allocated for local demand compare with a 86,25 % of non-used energy.

For de PV plus battery system, the cost-optimal size requires a PV capacity of 26,016 kW, a battery capacity of 116,143 kWh and a PV area of 162,599 m^2.

4.2.4 Guadalajara Comparative Assessment

Figure 4-22 and Figure 4-23 presents a comparison of results for the grid configurations evaluated in Guadalajara.

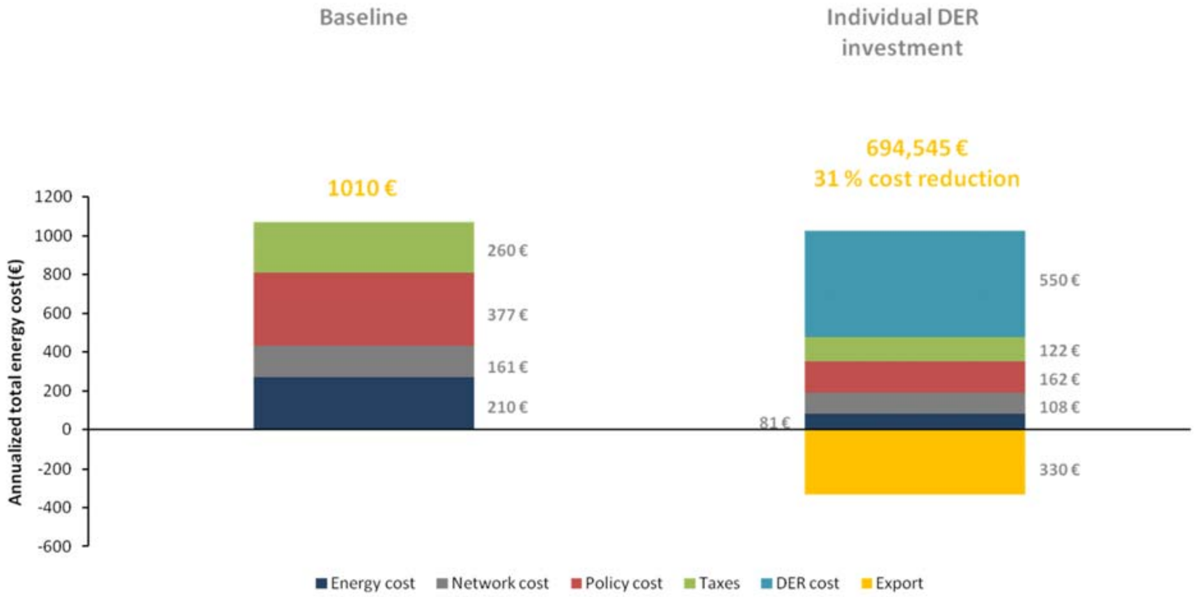


Figure 4-22: Guadalajara grid connected options comparative cost

The total energy cost for Individual DER investment is 694 €, there is a 31 % cost reduction respect baseline. The revenues from the electricity sales to the utility grid are 330 €. Average baseline energy cost is 0,187 €/kWh and average grid integrated energy cost is 0,128 €/kWh. As in Córdoba, main savings are due to the reduction (61 %) on energy cost by installing a PV system.

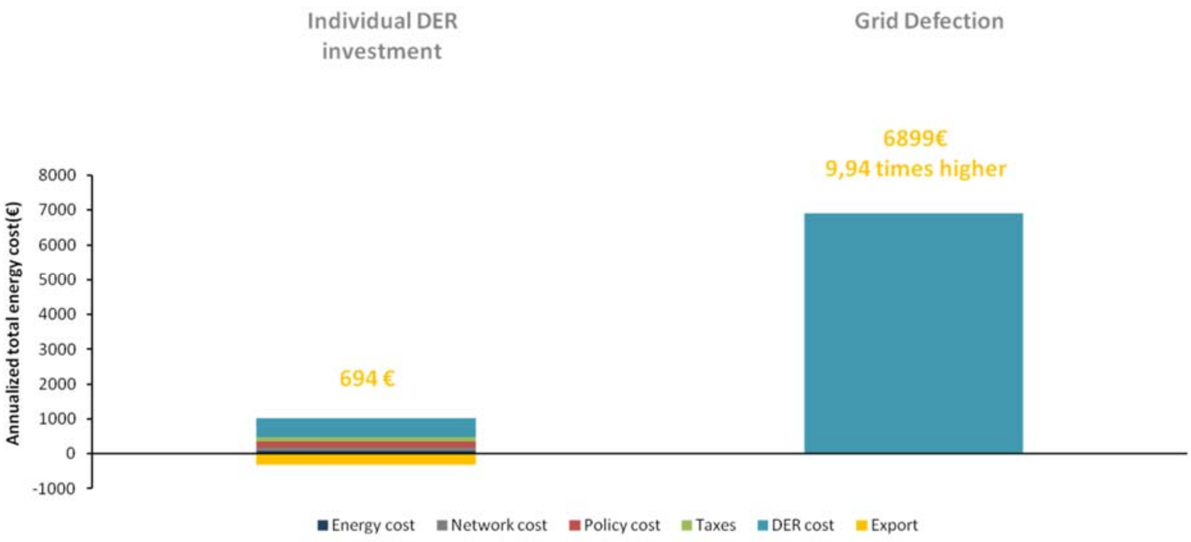


Figure 4-23: Guadalajara grid integrated and grid defection comparative cost

There is a 9,94 times grid integrated cost for grid defection option.

4.3 Oviedo

In Oviedo the consumption during one year was about 1,38 MWh of electricity. The consumer's load profile during the base year is illustrated in Figure 3-4 [Oviedo]. The data is obtained from the smart-meter measurements (Iberdrola, 2015).

4.3.1 Baseline case – Grid Supply

In the baseline case, the house has spent 338,163 € for its electricity bill over one year. Table 4-10 presents the total cost for baseline case. The contracted capacity is 2,483 kW.

Table 4-10: Oviedo total costs in grid supply configuration

Total electricity consumption (kWh)	**1.383,54**

Total energy costs (€)	**338,163**
Total electricity costs (€)	**338,163**
Energy costs	**28,888**
Network costs	**116,503**
Policy costs	**96,847**
Taxes	**95,925**
Average energy cost (€/kWh)	**0,244**

Figure 4-24 represents the electricity cost components.

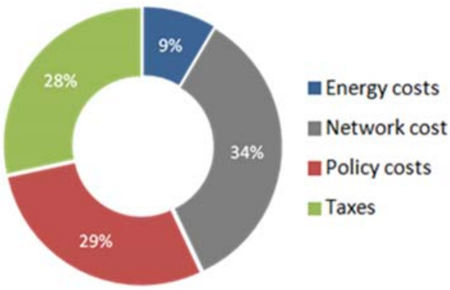


Figure 4-24: Oviedo electricity cost components (%) in grid supply configuration

Figure 4-25 illustrates a typical may week daily profile of the house in Oviedo.

Figure 4-25: Oviedo Energy balance for May week day in grid supply configuration

4.3.2 Grid Integrated

The monthly average solar irradiance and temperature data for Oviedo are obtained from (Energy Plus, 'Weather Data by Region | Energy Plus,' 2016). See Apendix A and Apendix B.

The techno economic data of household level DERs used for this location is the same that one for Córdoba and Guadalajara (see Table 4-5).

Table 4-11 presents the total cost for Grid Integrated case in Oviedo.

Table 4-11: Oviedo total costs in grid integrated configuration

Total utility electricity consumption (kWh)	**1.041,453**
Total electricity self-consumption (kWh)	**347,866**
Total energy costs (€)	**311,536**
Total electricity costs (€)	**281,100**
Energy costs	**23,864**
Network costs	**111,980**
Policy costs	**72,901**
Taxes	**72,355**
DER costs (€)	**46,197**
Revenues from Electricity sales (€)	**15,762**
Average energy cost (€/kWh)	**0,224**

Under this grid scheme, the house receives 1041,453 kWh (75 %) of electricity directly from the grid. The remaining demand is satisfied by the PV system, 347,866 (25 %), very low value compared to Córdoba (52 %) and Guadalajara (57 %).

The total energy cost is 311,536 €, the electricity costs are 281,100 € and the revenues from the electricity sales are 15,762 €. In this case, the contracted capacity is 1,755 kW.

Figure 4-26 and Figure 4-27 shows the energy balance for grid integrated option for two different months in Oviedo. In May week typical day, the PV output is mainly allocated for local use, providing for the 100 % local load between 7:00 am and 8:00 pm. The surplus PV generation is exported to the grid.

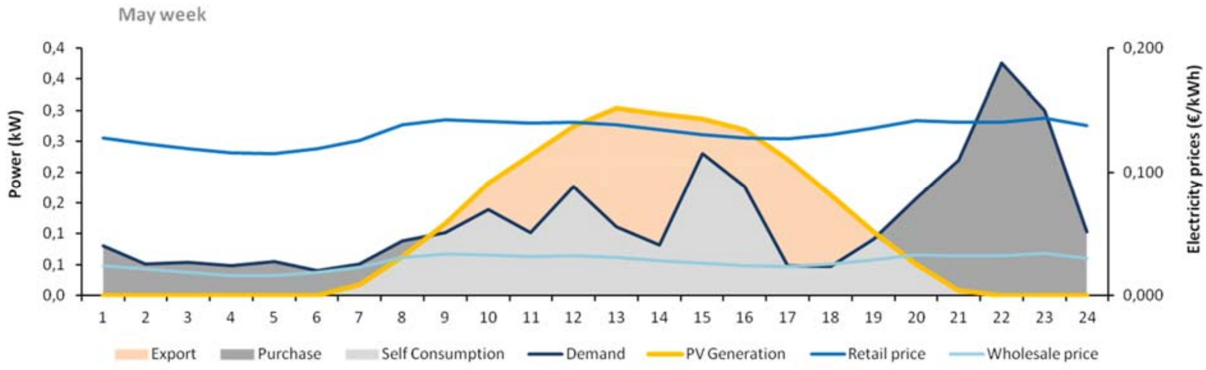


Figure 4-26: Oviedo Energy balance for May week day in grid integrated configuration

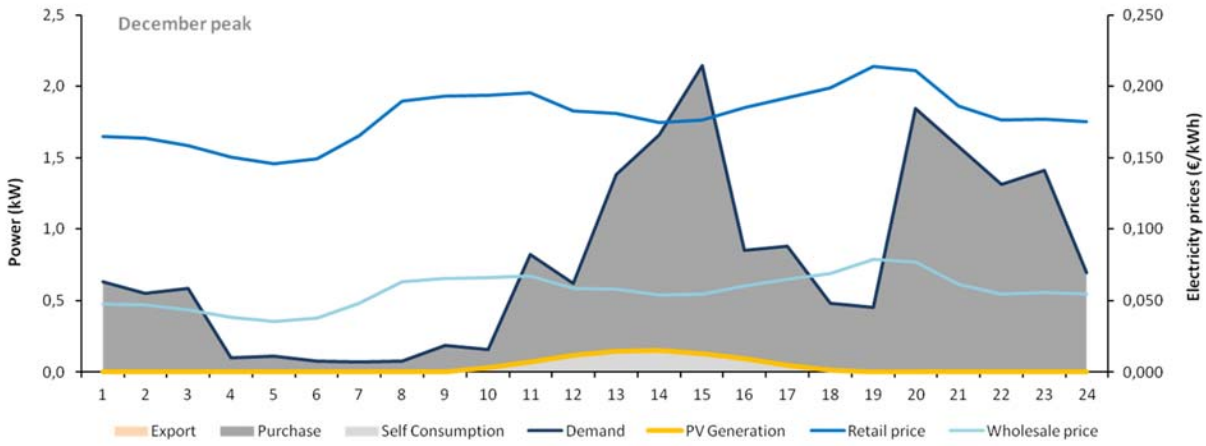


Figure 4-27: Oviedo Energy balance for December peak day in grid integrated configuration

In December PV output is not sufficient to meet all the local demand during PV generation hours, it is a very low value compared to Córdoba and Guadalajara. There is no electricity injected to the grid and the percentage of electricity purchased from the grid is much higher with respect to the other locations.

Figures below present the annual electricity consumption (Figure 4-28) and the annual PV generation (Figure 4-29).

Total Electricity Consumption (Kwh)	**1.389,319**
Electricity Purchase	**1.041,453**
Electricity self-consumption	**347,866**

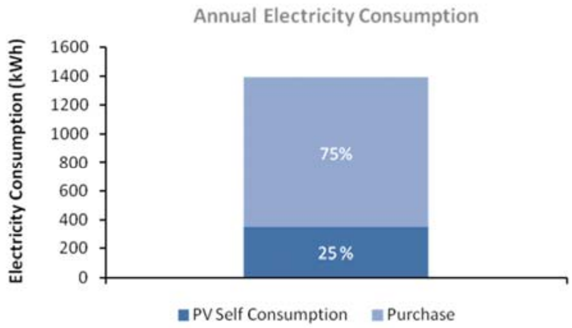


Figure 4-28: Oviedo annual electricity consumption in grid integrated configuration

PV Generation (Kwh)	**681,828**
Electricity Export	**333,962**
Electricity self-consumption	**347,866**

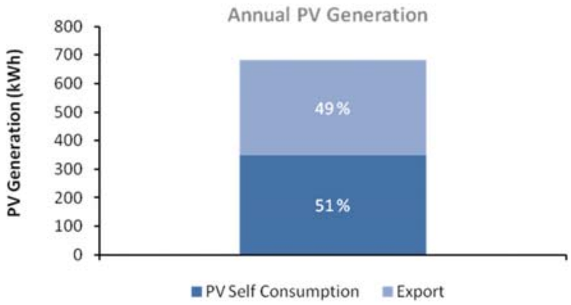


Figure 4-29: Oviedo annual PV generation in grid integrated configuration

In Oviedo, the cost-optimal PV system size requires a PV capacity of 0,543 kW and a PV area of 3,396 m^2.

4.3.3 Grid Defection

Total costs for Oviedo are illustrated in table below.

Table 4-12: Oviedo total costs in grid defection configuration

Total utility electricity consumption (kWh)	**0,000**
Total electricity self-consumption (kWh)	**1.446,790**
Total energy costs (€)	**3.806,155**
Total purchased electricity costs (€)	**0,000**

DER costs (€)	**3.806,155**
Average energy cost (€/kWh)	**2,630**

In this case, the total demand is satisfied by the PV-battery system and there is no utility electricity consumption. The total energy cost is 3806,155 €, approx. 12 times higher than grid integrated option.

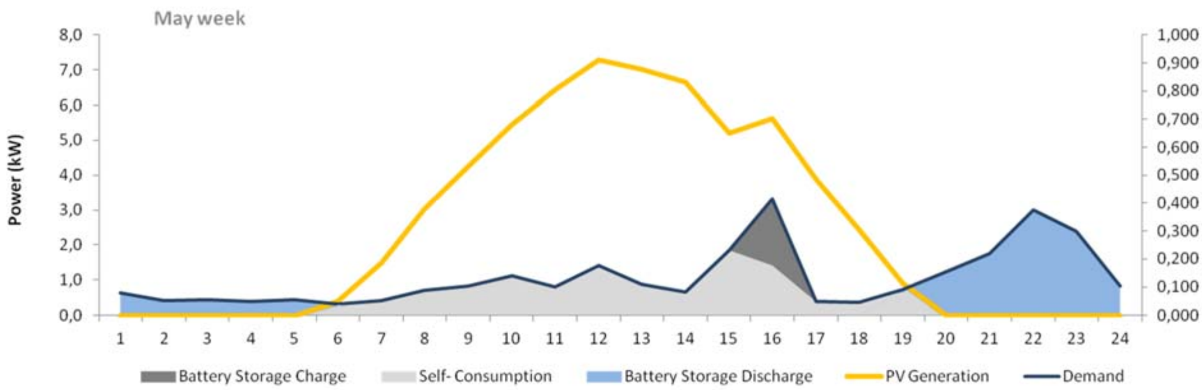


Figure 4-30: Oviedo Energy balance for May week day for grid defection option

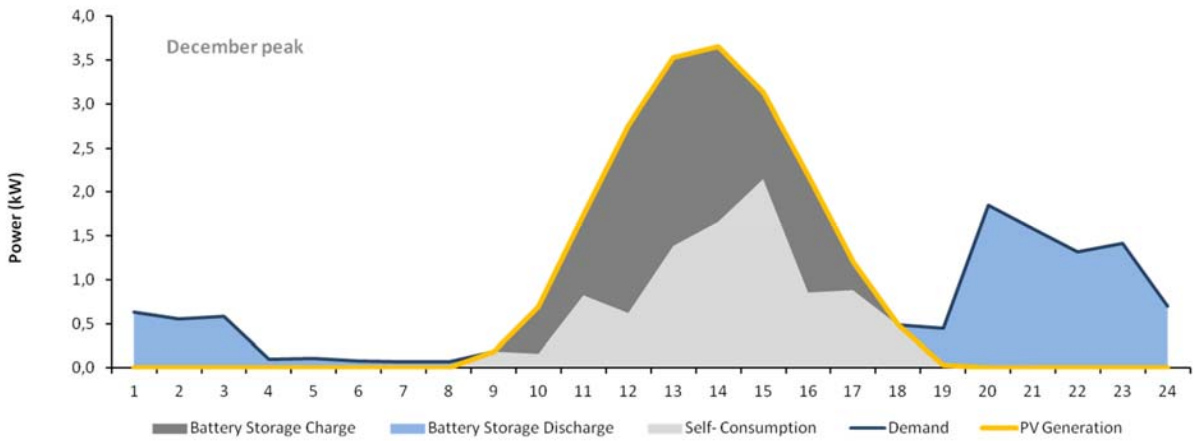


Figure 4-31: Oviedo Energy balance for December peak day for grid defection option

The total demand is satisfied by the PV-battery system and there is no utility electricity consumption. In December peak typical day, PV generation is used to charge the battery and there is non-used energy as it occurs for week days of May.

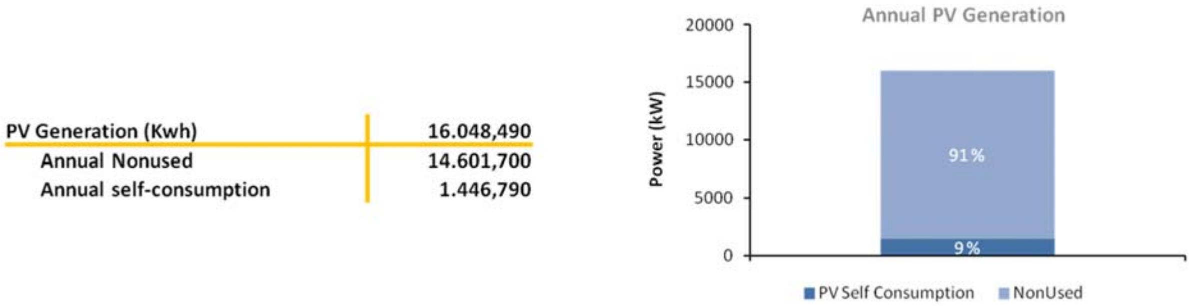


Figure 4-32: Oviedo annual PV generation in grid defection configuration

Only a 9 % of total PV generation is allocated for local demand compare with a 91 % of non-used energy.

For the PV plus battery system, the cost optimal size requires a PV capacity of 12,889 kW, a battery capacity of 64,411 kWh and a PV area of 80,624 m^2.

4.3.4 Oviedo Comparative Assessment

Figure 4-33 and Figure 4-34 presents a comparison of results for the grid configurations evaluated in Oviedo.

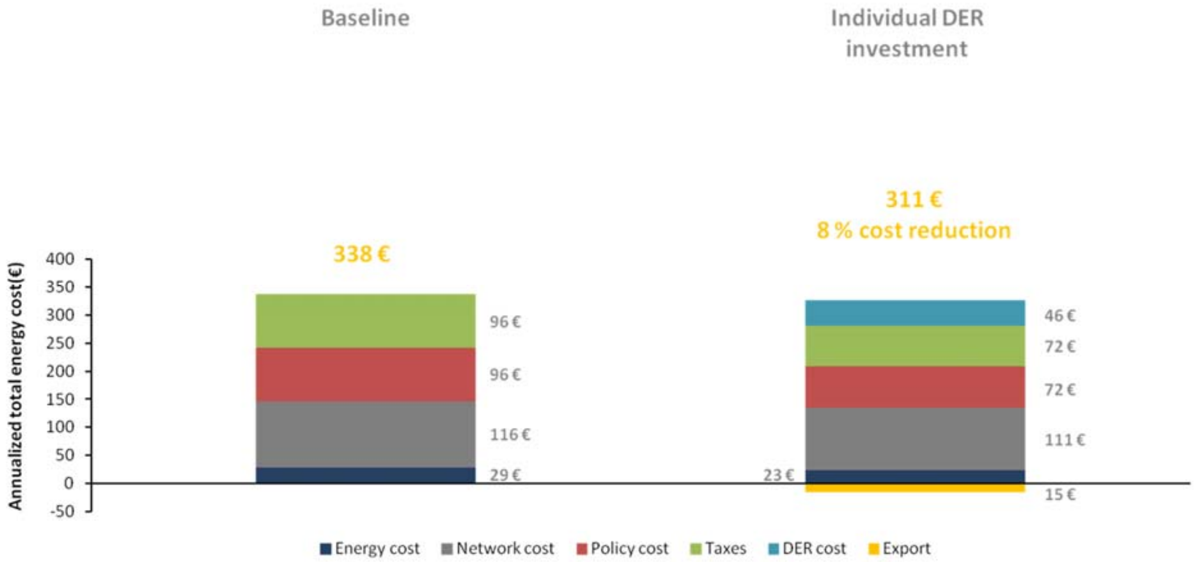


Figure 4-33: Oviedo grid connected options comparative cost

The total energy cost for Individual DER investment is 338 €, there is a 8 % cost reduction respect baseline. The revenues from the electricity sales to the utility grid are 15,762 €. Average baseline energy cost is 0,244 €/kWh and average grid integrated energy cost is 0,224 €/kWh. Here, there is not a significant cost reduction (8 %) from baseline case.

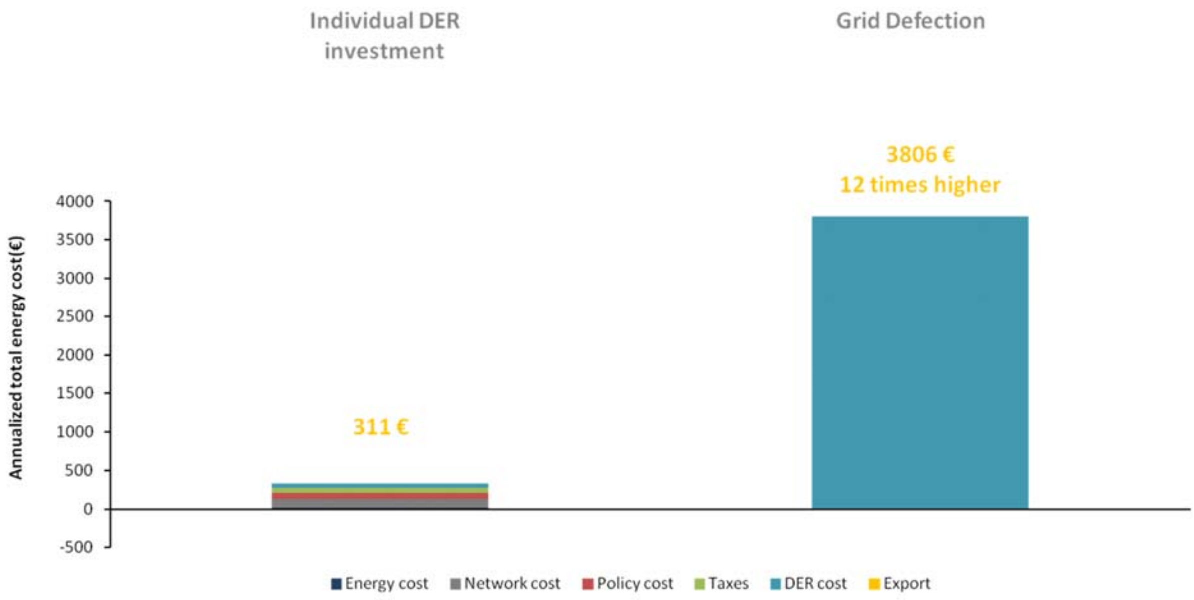


Figure 4-34: Oviedo grid integrated and grid defection comparative cost

The cost for grid defection is about 12 times higher compared with grid integrated case.

4.4 Locations Comparative Assessment

This section compares optimal system results for the different grid configurations and locations. Figure 4-35 summarizes the cost results for Córdoba, Guadalajara y Oviedo.

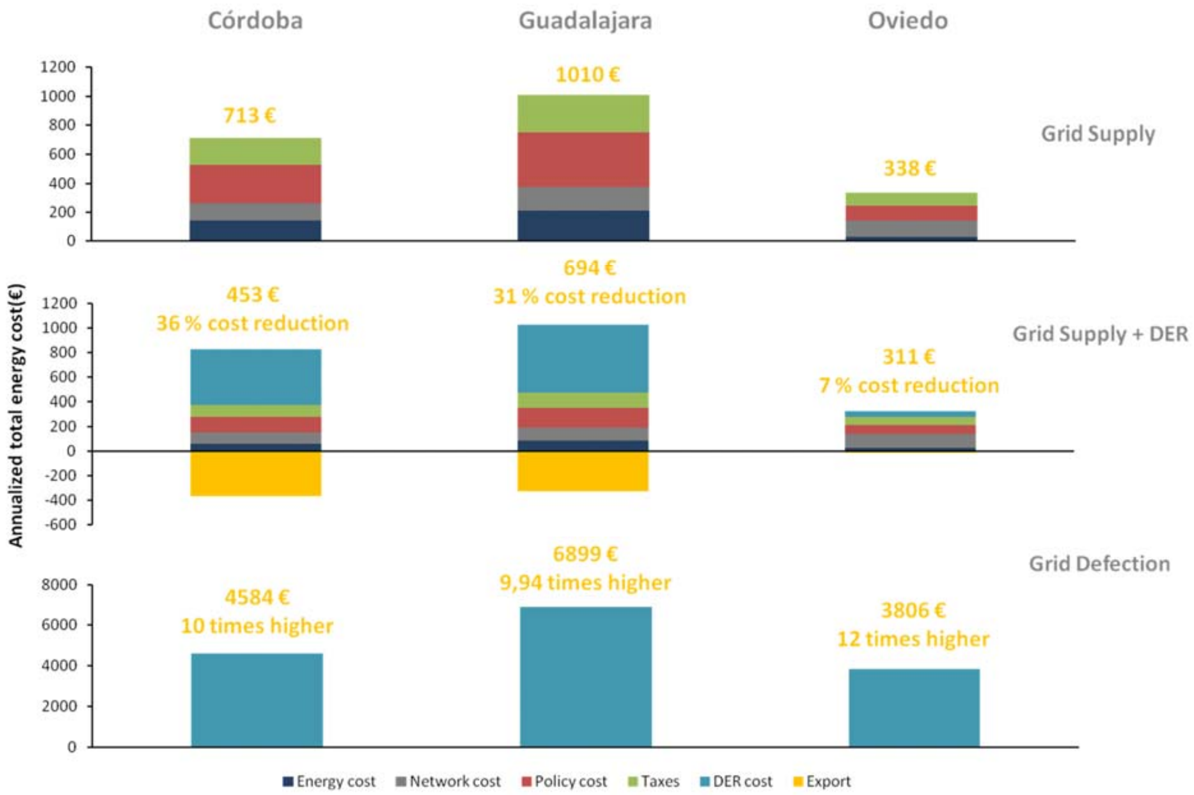


Figure 4-35: Energy cost summary

For the sense of comparison, it was carried out a normalization based on Electricity Consumption taking Córdoba as reference in order to obtain a similar energy consumption among the different locations. The normalization factor for Guadalajara is 0,7 and for Oviedo is 2,74. Table below summarizes the normalized cost results.

Table 4-13: Normalized cost results

	Córdoba	Guadalajara	Oviedo
		Grid Supply	
Total electricity consumption (kWh)	3.794,107	3.789,847	3.795,051
Total energy costs (€)	**713,301**	**709,118**	**927,581**
		Grid Integrated	
Total utility electricity consumption (kWh)	**1.813,884**	**1.628,022**	**2.857,368**
Total electricity self-consumption (kWh)	**1.983,049**	**2.161,583**	**937,484**
Total energy costs (€)	**453,086**	**487,570**	**854,561**
Total electricity costs (€)	**371,233**	**333,125**	**771,187**
DER costs (€)	**453,737**	**386,552**	**126,457**

Revenues from Electricity sales (€)	**371,885**	**232,107**	**43,083**
		Grid Defection	
Total electricity self-consumption (kWh)	**3.925,331**	**3.897,644**	**3.968,805**
Total energy costs (€)	**4.584,741**	**4.916,757**	**10.010,327**
DER costs (€)	**4.584,741**	**4.916,757**	**10.010,327**

The feasibility of renewable technologies is critically dependent on the location's richness in terms of energy resources (e.g., GHI for PV systems).

We can see that the results for locations further south, Cordoba and Guadalajara with lower latitude and best GHI values obtained a total cost of energy considerably better than Oviedo.

Figure 4-36 summarizes the normalized cost results for Córdoba, Guadalajara y Oviedo.

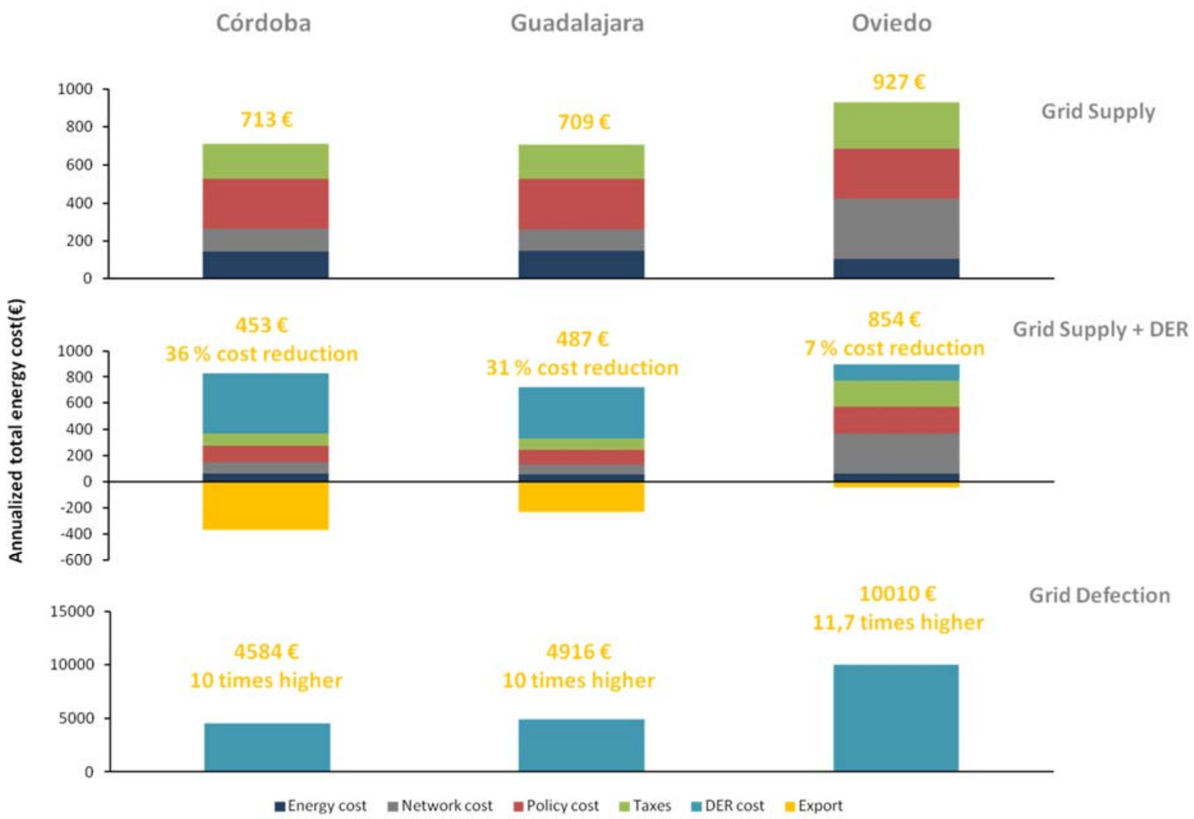


Figure 4-36: Normalized Energy cost summary

By comparing these results for the different grid configurations, it seems that the choice of grid integrated is the most economical option. In Córdoba, 453 € versus 713 € (grid supply) or 4584 (grid defection); in Guadalajara, 487 € versus 709 € (grid supply) or 4916 (grid defection); and in Oviedo, 854 € versus 927 € (grid supply) or 10010 (grid defection).

As seen from the above results, there is a significant increase in network cost in Oviedo compared with Córdoba and Guadalajara. In grid supply option, Oviedo network cost is around 62 % higher than Córdoba and Guadalajara. In grid integrated case, network cost in Oviedo is a 70 % higher compared with Córdoba and Guadalajara.

Correlating results with input data reveals higher peaks demand in Oviedo load profiles compared with the two other locations as a result of upward normalization.

With current costs, grid defection is not economically rationale, this options is on the order of 10 times more expensive.

4.5 Sensitivity Analysis

In the previous chapter, a few cases were studied for optimal economic selection, of the grid configuration system. The previous analyses are followed up by a sensitivity analysis to further investigate the effects of variations in important input parameters. In this we assess the impact of various techno-economic parameters, namely Maximum space available for PV, Export option, DER capital cost and Interest rate, on the economic feasibility of grid-connected PV-Battery systems.

4.5.1 Córdoba

The following figures summarize results in Córdoba:

Total Energy cost	Scenario 1	Scenario 2	%
Rooftop PV space (100 -> 25 m^2)	453,086	467,454	3,07
No Export	453,086	575,899	21,325
DER Capital cost (5% cost reduction)	453,086	371,583	-17,988
Interest rate (0,05 -> 0,04)	453,086	410,147	-9,47

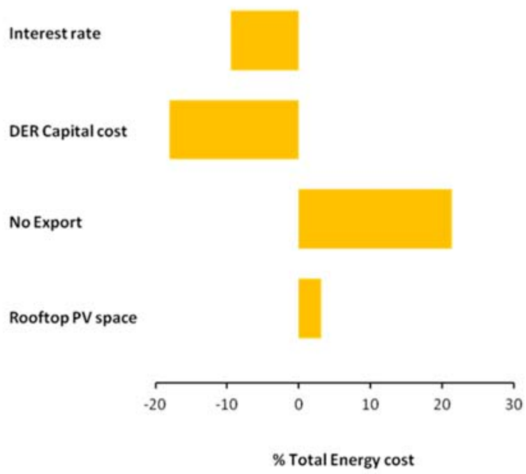


Figure 4-37: Impact of changes in the parameters on the Total energy cost in Córdoba

By decreasing the rooftop PV area, from 100 m^2 to 25 m^2, the total energy cost increases to some extent, but not significantly, 3%. This is because the available space is not exhausted in the grid-integrated case before sensitivity analysis.

In the case where customers are not compensated for any export of energy to the grid there is a significant increment of 21 % in the total energy cost, due to the revenues for electricity sales are 0 €.

If we investigate the impact of a probable decline in DER technology capital costs (5 % cost reduction) on the economics of installing a PV-Battery system, this decrease helps bring down the total energy cost, about 18 % cost reduction.

For Córdoba, lowering the interest rate by a 1 %, decreases the total cost in the optimal system in a 9,47 %.

4.5.2 Guadalajara

For Guadalajara, the analysis presents aligned results with it have obtained in Córdoba. Here, sensitivity to the parameter variations on total energy cost is lower than in previous case. Reduction in DER capital cost and interest rate returns a decrease in the output, while there is no option to sell electricity excess into the grid, the cost increases by a 13,9 %.

Guadalajara results are summarized below.

Total Energy cost

	Scenario 1	Scenario 2	%
Rooftop PV space (100 -> 25 m²)	487,57	488,849	0,26
No Export	487,57	566,302	13,9
DER Capital cost (5% cost reduction)	487,57	466,365	-4,54
Interest rate (0,05 -> 0,04)	487,57	452,115	-7,27

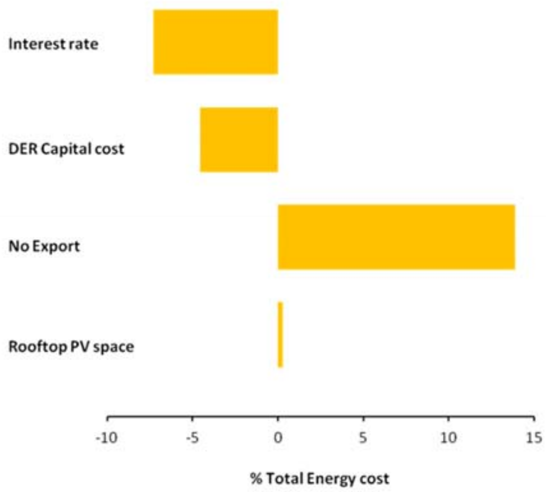


Figure 4-38: Impact of changes in the parameters on the Total energy cost in Guadalajara

4.5.3 Oviedo

Figure below summarizes results in Oviedo:

Total Energy cost

	Scenario 1	Scenario 2	%
Rooftop PV space (100 -> 25 m²)	854,561	854,561	0
No Export	854,561	877,922	2,66
DER Capital cost (5% cost reduction)	854,561	846,498	-0,94
Interest rate (0,05 -> 0,04)	854,561	852,284	-0,26

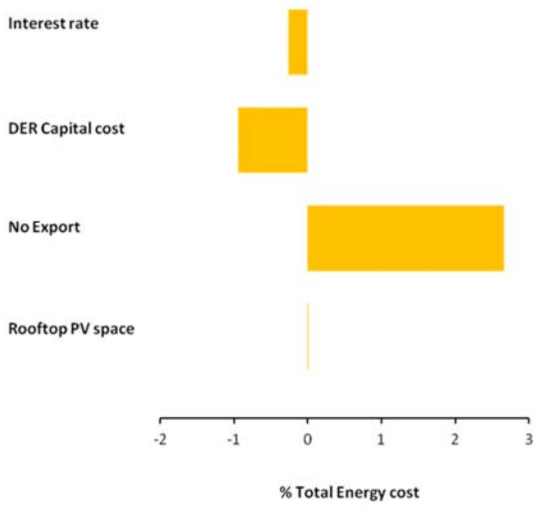


Figure 4-39: Impact of changes in the parameters on the Total energy cost in Oviedo

Unlike the other two places, for Oviedo, the changes in the parameters have a limited impact on the optimal system cost, the most significant by around 2,66 % if not enabled the option to export electricity to the grid.

5 Conclusions and Future Research

5.1 Conclusions

This study is an attempt to assess the economic feasibility of leaving the grid in different geographies. Three different locations in Spain, Córdoba, Guadalajara and Oviedo are studied to determine grid defection and grid integrated energy cost. The analysis is done for an off grid solar PV plus battery system using The Distributed Energy Resources Customer Adoption Model (DER-CAM). DER-CAM software model is used to determine the system annualized total energy cost at each location. This annualized total cost of energy is compared with the baseline case, grid supply and with the grid integrated network configuration to determine the economic option.

Analysis results reveal the considerable variation in geographic and grid configurations across these places. However, the results follow a similar trend in grid defection configuration for all locations, with a rough increase of 10 times compared with grid integrated option. Based on this, it can be concluded that grid integrated and grid defection options make more economic sense in places where grid electricity is expensive due to the high effective cost of this grid power. This is of course for cases where utility electricity is already available. For rural remote places which do not have access to grid power, off-grid system may still be the only economical solution.

In summary, it is evident that there exists a conflicting condition. For a grid integrated option, a small PV system is less costly, but is unable to satisfy a higher percentage of grid independence. Therefore, it implies grid connection is necessary. On the other hand, 100% grid independence is only possible with a very large PV battery system which is subject to significant DER capital costs. Off grid systems need to be oversized to guarantee stand-alone reliable service. However, according to PV generation results in grid defection option, such system will have a very high unused energy which could be a revenue source higher than the annual grid connection fee (supply charge).

Therefore, considering the economic advantage of grid connection for selling the surplus energy, grid disconnection is not the best option with current costs. This recommendation will be stronger as PV plus battery technologies costs decline overtime.

We used DER-CAM decision support software of Chapter 2 to investigate the impact of various parameters, namely rooftop PV area, not available export option, DER capital cost and interest rate, on the economic feasibility of grid-connected PV-Battery systems. We found that the energy cost of the right solar PV plus battery system is significantly sensitive to all the parameters. In all cases, the analysis reveals that a decline in DER technology capital costs and lower interest rate, helps bring down the total energy cost. By the other hand, decreasing the rooftop PV area and if the option to export electricity to the grid is not possible, translate into higher energy cost values. In the case where customers are not compensated for the revenues from electricity sales, there is a significant increment in the total energy cost.

Although the analysis quantitatively shows the advantage of southern latitude locations (Córdoba and Guadalajara), full grid independence is economic infeasible for all of the three geographies for the houses modeled.

Regardless of how they are implemented, solar PV plus battery systems will play an important role in the electricity system of the future.

5.2 Future Research

The analysis approach carried out in this thesis provides a guide to future research.

The use of DER optimization tools like DER-CAM can help investigate Grid Integrated and Grid Defection configurations with other onsite generation technologies, such as combined heat-and-power, small wind and biomass, with other storage technologies (heat) and with a backup system like a diesel generator. Studies comparing Grid Defection estimates for different variants of DER systems can serve as important inputs to policy formulation for such new grid configurations.

The adoption of the PV plus battery systems can create a range of technical challenges and create electricity system reliability issues. Additional research could be conducted to investigate the feasibility of solar PV systems with battery storage systems to supply its electricity demand at a given reliability.

In the grid connected case, the model used does not consider the increase of contracted capacity to export PV generation. Additional study should include this option in the model and evaluate the network charges.

The scope can be extended to conduct it at a greater scale by studying more markets, in a higher number of regions or countries and using more than one optimization tool. The analysis technique can also be employed to implement a much more detailed local level analysis within particular energy market to identify variations in Grid Defection within that market.

This study modeled a grid defection system for a single owner. It should be pointed out that a group of customers with common space sharing a single large PV system and a battery bank in coordination could be a way to bring grid defection for a community of consumers or to entire neighborhoods. This option can achieve lower costs for electricity self-provision.

Other sensitivity analyses could be carried out over parameters such as system size, electricity tariff, feed-in-tariff, .. which may change the economics of grid integrated and grid defected options.

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7 Appendices

7.1 Apendix A: Temperature

Temperature – Córdoba

Month	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
January	7,832	7,448	7,113	6,806	6,513	6,081	5,739	5,400	5,432	6,171	7,552	9,535	11,700	13,661	15,061	15,684	15,358	14,284	12,826	11,494	10,416	9,584	8,884	8,184
February	8,746	8,293	7,657	7,364	7,021	6,750	6,425	6,129	6,496	7,439	9,004	11,050	13,393	15,429	16,929	17,711	17,557	16,532	14,918	13,379	12,107	10,939	10,057	9,404
March	10,326	9,797	9,387	8,926	8,526	8,042	7,684	7,648	8,368	9,745	11,710	14,013	16,410	18,490	19,903	20,668	20,465	19,423	17,794	15,890	14,213	12,939	11,900	11,016
April	12,033	11,487	11,067	10,543	10,073	9,673	9,563	9,933	11,003	12,577	14,793	17,003	19,157	21,040	22,337	22,853	22,587	21,517	19,910	18,003	16,243	14,850	13,687	12,813
May	15,368	14,710	14,068	13,461	12,906	12,639	12,765	13,584	14,948	16,952	19,361	21,774	24,239	26,139	27,423	27,787	27,439	26,252	24,523	22,403	20,397	18,710	17,352	16,306
June	19,183	18,370	17,633	16,873	16,100	15,947	16,307	17,197	18,800	20,820	23,383	25,953	28,353	30,327	31,673	32,157	31,850	30,750	28,903	26,807	24,547	22,610	21,143	20,023
July	22,503	21,616	20,829	20,090	19,342	19,055	19,255	20,061	21,813	24,039	26,794	29,597	32,300	34,552	36,219	36,897	36,594	35,442	33,565	31,165	28,687	26,584	24,842	23,565
August	22,635	21,974	21,445	20,739	20,110	19,494	19,268	19,987	21,435	23,465	26,187	29,048	31,829	34,306	35,929	36,484	36,223	34,977	33,019	30,526	28,245	26,371	24,813	23,545
September	20,193	19,740	19,150	18,617	18,097	17,517	17,330	17,723	18,803	20,673	23,040	25,743	28,347	30,537	32,013	32,607	32,043	30,730	28,870	26,663	24,780	23,243	22,073	21,160
October	15,848	15,506	15,097	14,590	14,139	13,655	13,155	13,168	13,916	15,526	17,597	19,994	22,484	24,400	25,690	25,919	25,365	23,981	22,087	20,455	19,068	17,910	17,052	16,329
November	10,537	10,410	10,127	9,690	9,220	8,867	8,590	8,370	8,693	9,850	11,590	13,830	16,220	18,117	19,377	19,590	18,940	17,507	16,057	14,653	13,613	12,680	11,853	11,190
December	7,919	7,684	7,342	7,003	6,681	6,252	5,932	5,555	5,587	6,445	7,910	10,013	12,219	14,155	15,490	15,774	15,303	13,929	12,635	11,413	10,448	9,584	8,913	8,342

Temperature – Guadalajara

Month	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
January	4,229	3,990	3,777	3,490	3,145	2,971	2,619	2,368	2,384	2,945	4,100	5,594	7,277	8,732	9,765	10,148	9,826	8,906	7,816	6,906	6,123	5,481	4,981	4,484
February	5,193	4,725	4,400	4,121	3,800	3,493	3,225	3,104	3,368	4,025	5,414	7,082	8,954	10,475	11,629	12,104	11,861	10,946	9,818	8,614	7,514	6,725	6,139	5,575
March	6,448	5,984	5,606	5,268	4,952	4,629	4,339	4,387	5,035	6,048	7,719	9,735	11,687	13,348	14,568	15,061	14,810	13,845	12,419	10,906	9,635	8,577	7,784	7,074
April	8,790	8,203	7,773	7,500	7,033	6,703	6,737	7,127	8,120	9,637	11,367	13,353	15,290	16,763	17,797	18,200	17,833	16,800	15,510	13,873	12,300	11,163	10,180	9,407

May	12,068	11,590	10,935	10,400	9,752	9,603	9,894	10,697	11,968	13,613	15,642	17,652	19,674	21,158	22,071	22,387	22,013	20,929	19,535	17,806	16,023	14,619	13,455	12,674
June	16,027	15,183	14,630	14,057	13,480	13,297	13,810	14,703	16,320	18,177	20,297	22,500	24,730	26,370	27,440	27,797	27,330	26,350	24,797	22,887	20,907	19,187	17,810	16,873
July	19,339	18,674	17,974	17,300	16,487	16,361	16,790	17,648	19,200	21,406	23,726	26,303	28,677	30,623	31,965	32,423	32,071	30,897	29,219	27,065	24,765	22,923	21,403	20,300
August	19,065	18,406	17,852	17,313	16,806	16,294	16,184	16,887	18,287	20,268	22,597	25,094	27,665	29,677	30,948	31,455	31,129	30,019	28,097	26,013	23,958	22,313	20,997	19,906
September	16,273	15,957	15,483	14,897	14,353	13,870	13,723	14,037	15,150	16,867	19,073	21,540	23,967	25,850	26,963	27,407	26,907	25,587	23,690	21,777	20,243	18,827	17,813	16,967
October	11,774	11,610	11,181	10,700	10,397	9,910	9,503	9,568	10,413	11,797	13,616	15,742	17,765	19,516	20,458	20,639	20,016	18,777	17,042	15,723	14,619	13,706	12,832	12,287
November	7,323	7,043	6,793	6,500	6,250	6,020	5,710	5,487	5,783	6,650	8,127	9,907	11,723	13,277	14,210	14,297	13,663	12,397	11,233	10,243	9,393	8,603	8,197	7,620
December	4,577	4,384	4,161	3,858	3,674	3,355	3,255	2,871	2,945	3,548	4,729	6,306	7,945	9,439	10,303	10,571	9,997	9,061	8,058	7,168	6,394	5,803	5,394	4,961

Temperature – Oviedo

Month	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
January	6,481	6,165	5,987	5,735	5,365	5,158	4,910	4,655	4,568	4,997	5,803	7,274	8,852	10,416	11,452	11,968	11,752	10,984	9,910	9,048	8,255	7,671	7,171	6,700
February	7,125	6,804	6,479	6,246	5,886	5,707	5,575	5,332	5,457	5,989	7,064	8,529	10,043	11,593	12,732	13,293	13,175	12,521	11,411	10,339	9,421	8,654	8,075	7,596
March	7,548	7,223	6,835	6,697	6,339	6,013	5,845	5,739	6,106	7,132	8,423	9,984	11,655	13,013	14,132	14,690	14,542	13,861	12,761	11,452	10,394	9,448	8,690	8,152
April	8,220	7,923	7,600	7,213	6,943	6,553	6,533	6,873	7,547	8,560	9,927	11,387	12,783	13,983	14,757	15,163	15,047	14,393	13,400	12,220	11,020	10,043	9,283	8,757
May	10,671	10,161	9,877	9,497	9,181	9,074	9,177	9,697	10,510	11,574	12,884	14,187	15,426	16,439	17,129	17,416	17,203	16,623	15,735	14,684	13,461	12,477	11,735	11,190
June	13,637	13,247	12,930	12,513	12,223	12,083	12,243	12,840	13,607	14,690	15,900	17,187	18,430	19,353	20,090	20,280	20,203	19,633	18,813	17,740	16,627	15,517	14,863	14,220
July	15,906	15,455	15,068	14,716	14,481	14,294	14,455	14,913	15,684	16,745	17,977	19,274	20,542	21,581	22,203	22,574	22,529	21,955	21,116	20,116	18,977	17,852	17,048	16,445
August	16,306	16,097	15,790	15,416	15,016	14,639	14,703	15,113	15,774	16,716	18,006	19,284	20,690	21,742	22,468	22,826	22,742	22,161	21,310	20,226	19,129	18,113	17,326	16,771
September	15,413	15,063	14,743	14,307	14,083	13,813	13,573	13,753	14,423	15,470	16,890	18,467	20,023	21,347	22,160	22,577	22,327	21,647	20,560	19,263	18,063	17,110	16,443	15,843
October	12,368	12,142	11,865	11,587	11,274	11,019	10,726	10,690	11,152	12,077	13,332	14,923	16,487	17,684	18,539	18,852	18,458	17,632	16,490	15,423	14,510	13,865	13,274	12,761
November	9,130	8,833	8,537	8,313	7,953	7,700	7,550	7,300	7,367	8,053	9,210	10,817	12,500	13,910	14,893	15,213	14,633	13,650	12,537	11,623	10,890	10,173	9,727	9,310
December	7,574	7,303	7,087	6,890	6,629	6,477	6,277	6,048	5,994	6,394	7,274	8,652	10,158	11,668	12,561	12,852	12,481	11,655	10,632	9,965	9,265	8,781	8,252	7,806

7.2 Apendix B: Solar insolation

Solar insolation – Córdoba

Month	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
January	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,10	0,21	0,31	0,37	0,40	0,39	0,32	0,21	0,09	0,02	0,00	0,00	0,00	0,00	0,00
February	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,15	0,27	0,37	0,44	0,48	0,47	0,42	0,32	0,18	0,06	0,00	0,00	0,00	0,00	0,00
March	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,12	0,25	0,39	0,50	0,57	0,57	0,54	0,48	0,37	0,24	0,11	0,02	0,00	0,00	0,00	0,00
April	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,08	0,22	0,36	0,48	0,58	0,64	0,65	0,62	0,54	0,41	0,27	0,14	0,04	0,00	0,00	0,00	0,00
May	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,16	0,30	0,44	0,60	0,72	0,77	0,77	0,74	0,65	0,53	0,38	0,23	0,08	0,01	0,00	0,00	0,00
June	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,18	0,33	0,49	0,63	0,75	0,81	0,83	0,80	0,72	0,59	0,44	0,29	0,13	0,03	0,00	0,00	0,00
July	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,17	0,35	0,52	0,67	0,79	0,87	0,89	0,87	0,77	0,63	0,48	0,31	0,14	0,03	0,00	0,00	0,00
August	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,12	0,29	0,46	0,62	0,75	0,83	0,86	0,82	0,73	0,60	0,43	0,26	0,09	0,01	0,00	0,00	0,00
September	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,20	0,36	0,51	0,63	0,69	0,70	0,64	0,56	0,43	0,28	0,12	0,02	0,00	0,00	0,00	0,00
October	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,12	0,28	0,39	0,49	0,55	0,55	0,50	0,40	0,27	0,13	0,03	0,00	0,00	0,00	0,00	0,00
November	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05	0,17	0,29	0,39	0,44	0,46	0,40	0,33	0,19	0,06	0,00	0,00	0,00	0,00	0,00	0,00
December	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,10	0,20	0,31	0,37	0,38	0,35	0,27	0,15	0,05	0,01	0,00	0,00	0,00	0,00	0,00

Solar insolation – Guadalajara

Month	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
January	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,07	0,15	0,22	0,26	0,29	0,28	0,21	0,13	0,06	0,01	0,00	0,00	0,00	0,00	0,00
February	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,12	0,22	0,32	0,36	0,36	0,35	0,29	0,19	0,09	0,02	0,00	0,00	0,00	0,00	0,00
March	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,10	0,22	0,33	0,39	0,44	0,47	0,44	0,38	0,29	0,18	0,08	0,01	0,00	0,00	0,00	0,00
April	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,08	0,20	0,32	0,41	0,49	0,54	0,57	0,54	0,44	0,36	0,24	0,12	0,03	0,00	0,00	0,00	0,00
May	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,15	0,28	0,41	0,53	0,61	0,65	0,62	0,58	0,53	0,43	0,31	0,19	0,07	0,01	0,00	0,00	0,00
June	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,19	0,32	0,46	0,54	0,63	0,71	0,72	0,68	0,61	0,52	0,40	0,25	0,11	0,02	0,00	0,00	0,00
July	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,19	0,36	0,51	0,66	0,74	0,80	0,81	0,79	0,70	0,59	0,44	0,28	0,13	0,03	0,00	0,00	0,00
August	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,14	0,29	0,46	0,59	0,68	0,76	0,76	0,73	0,65	0,53	0,38	0,22	0,07	0,01	0,00	0,00	0,00
September	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,19	0,32	0,45	0,55	0,61	0,62	0,57	0,49	0,38	0,24	0,10	0,01	0,00	0,00	0,00	0,00
October	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,10	0,22	0,33	0,42	0,44	0,47	0,43	0,34	0,22	0,09	0,01	0,00	0,00	0,00	0,00	0,00
November	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,12	0,22	0,29	0,33	0,31	0,29	0,22	0,12	0,04	0,00	0,00	0,00	0,00	0,00	0,00
December	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,08	0,16	0,22	0,24	0,27	0,25	0,18	0,10	0,03	0,00	0,00	0,00	0,00	0,00	0,00

Solar insolation – Oviedo

Month	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
January	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,05	0,12	0,19	0,25	0,27	0,25	0,21	0,14	0,06	0,01	0,00	0,00	0,00	0,00	0,00
February	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,09	0,17	0,26	0,32	0,35	0,33	0,28	0,20	0,11	0,04	0,00	0,00	0,00	0,00	0,00
March	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,08	0,18	0,27	0,34	0,40	0,42	0,41	0,38	0,29	0,17	0,08	0,02	0,00	0,00	0,00	0,00
April	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,06	0,15	0,25	0,33	0,42	0,47	0,50	0,50	0,43	0,34	0,24	0,13	0,04	0,01	0,00	0,00	0,00
May	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,11	0,21	0,30	0,38	0,46	0,52	0,50	0,49	0,46	0,38	0,28	0,18	0,07	0,01	0,00	0,00	0,00
June	0,00	0,00	0,00	0,00	0,00	0,01	0,05	0,12	0,22	0,32	0,42	0,48	0,53	0,55	0,52	0,46	0,40	0,30	0,19	0,10	0,03	0,00	0,00	0,00
July	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,11	0,22	0,32	0,41	0,46	0,51	0,54	0,53	0,48	0,42	0,33	0,22	0,11	0,03	0,00	0,00	0,00
August	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,07	0,18	0,29	0,37	0,43	0,49	0,51	0,49	0,45	0,38	0,29	0,17	0,07	0,01	0,00	0,00	0,00
September	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,12	0,23	0,35	0,42	0,46	0,46	0,43	0,38	0,29	0,19	0,08	0,02	0,00	0,00	0,00	0,00
October	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,06	0,16	0,26	0,33	0,37	0,38	0,33	0,28	0,19	0,10	0,02	0,00	0,00	0,00	0,00	0,00
November	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,09	0,18	0,24	0,29	0,31	0,27	0,20	0,11	0,04	0,00	0,00	0,00	0,00	0,00	0,00
December	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,05	0,12	0,19	0,25	0,26	0,22	0,16	0,09	0,03	0,00	0,00	0,00	0,00	0,00	0,00

7.3 Apendix C: Electricity consumption

Electricity consumption – Córdoba

Household	Month	Period	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
h1	January	week	0,585	0,335	0,114	0,106	0,118	0,124	0,091	0,159	0,174	0,128	0,120	0,146	0,198	0,503	0,759	0,586	0,553	0,566	0,753	0,778	0,726	0,766	0,668	0,594
h1	February	week	0,629	0,311	0,086	0,090	0,086	0,106	0,101	0,167	0,141	0,154	0,103	0,119	0,298	0,682	0,886	0,876	0,670	0,650	0,637	0,700	0,699	0,784	0,952	0,782
h1	March	week	0,699	0,503	0,197	0,161	0,124	0,120	0,116	0,215	0,243	0,325	0,325	0,307	0,314	0,459	0,812	0,670	0,494	0,498	0,501	0,692	0,624	0,753	0,780	0,801
h1	April	week	0,435	0,178	0,101	0,102	0,127	0,129	0,180	0,205	0,249	0,277	0,287	0,369	0,521	0,495	0,410	0,353	0,294	0,260	0,354	0,339	0,507	0,713	0,706	0,585
h1	May	week	0,255	0,197	0,162	0,167	0,164	0,168	0,231	0,237	0,299	0,213	0,235	0,346	0,644	0,542	0,298	0,275	0,281	0,223	0,212	0,227	0,234	0,357	0,279	0,303
h1	June	week	0,269	0,187	0,176	0,175	0,171	0,199	0,232	0,228	0,224	0,278	0,235	0,285	0,437	0,540	0,316	0,301	0,318	0,308	0,260	0,243	0,265	0,367	0,341	0,301
h1	July	week	0,583	0,432	0,333	0,248	0,211	0,263	0,340	0,245	0,292	0,331	0,340	0,379	0,766	0,631	0,328	0,358	0,358	0,353	0,312	0,283	0,291	0,484	0,452	0,490
h1	August	week	0,273	0,211	0,198	0,222	0,266	0,251	0,274	0,322	0,309	0,255	0,312	0,350	0,418	0,522	0,369	0,397	0,377	0,346	0,375	0,391	0,350	0,528	0,431	0,341
h1	September	week	0,244	0,186	0,175	0,172	0,172	0,169	0,231	0,228	0,254	0,263	0,291	0,331	0,562	0,402	0,306	0,301	0,294	0,248	0,247	0,256	0,348	0,337	0,311	0,281
h1	October	week	0,228	0,166	0,160	0,146	0,156	0,153	0,204	0,187	0,262	0,227	0,256	0,307	0,551	0,489	0,419	0,404	0,275	0,245	0,253	0,282	0,307	0,397	0,301	0,278
h1	November	week	0,469	0,331	0,188	0,127	0,117	0,129	0,106	0,155	0,138	0,262	0,266	0,298	0,250	0,711	0,665	0,422	0,356	0,387	0,423	0,428	0,489	0,616	0,579	0,590

h1	December	week	0,611	0,380	0,166	0,118	0,118	0,109	0,119	0,157	0,151	0,204	0,232	0,258	0,362	0,464	0,420	0,375	0,351	0,435	0,603	0,707	0,772	0,893	0,687	0,696
h1	January	peak	1,125	0,867	0,670	0,465	0,325	0,182	0,164	0,250	1,050	1,403	1,928	1,889	2,457	2,566	2,241	1,207	1,262	1,277	1,167	1,519	1,250	1,739	1,275	1,004
h1	February	peak	1,160	0,663	0,433	1,051	0,298	0,165	0,172	1,822	1,917	1,536	1,033	1,385	1,726	1,861	1,772	2,749	1,983	1,709	1,424	1,395	1,836	2,121	1,887	1,264
h1	March	peak	1,133	1,158	0,574	0,533	0,278	0,287	0,341	0,612	0,651	1,151	1,433	0,895	1,145	1,652	2,678	1,680	1,167	1,708	1,130	1,583	1,377	1,612	1,527	1,374
h1	April	peak	0,737	0,527	0,177	0,175	0,180	0,169	0,316	1,179	1,310	1,762	1,811	1,838	1,774	1,792	1,585	1,651	1,125	1,142	1,023	0,934	1,346	1,880	1,705	1,236
h1	May	peak	0,602	0,311	0,236	0,225	0,213	0,257	0,893	1,478	1,307	1,400	1,786	1,472	2,076	1,782	0,961	0,561	0,531	0,764	0,668	0,418	0,661	0,949	0,827	0,424
h1	June	peak	0,618	0,266	0,254	0,245	0,216	0,259	0,845	0,738	1,167	1,409	1,495	0,904	1,240	2,105	0,627	1,398	0,557	0,467	0,552	0,538	0,529	1,327	0,497	0,478
h1	July	peak	1,452	1,402	0,969	0,704	0,465	0,893	2,274	1,731	1,733	1,364	1,352	1,316	1,889	1,942	0,553	0,427	0,383	0,609	0,544	0,408	0,501	1,223	1,027	1,113
h1	August	peak	1,078	0,706	0,302	0,787	1,326	1,218	1,277	1,377	0,955	0,839	1,406	2,054	1,467	1,111	1,072	1,581	1,422	0,659	1,445	1,866	1,211	1,193	1,523	0,656
h1	September	peak	0,407	0,278	0,221	0,232	0,204	0,230	0,293	0,903	1,311	1,554	1,502	1,260	1,208	0,976	0,773	1,376	0,592	0,390	0,547	1,059	1,205	1,530	0,511	0,378
h1	October	peak	0,652	0,602	0,537	0,205	0,206	0,212	0,292	0,547	1,091	1,116	0,777	1,243	1,830	1,512	1,242	1,729	0,680	0,536	0,817	1,006	1,609	1,492	0,642	0,456
h1	November	peak	1,160	0,984	1,073	0,179	0,170	0,177	0,209	0,404	0,828	1,225	1,697	1,861	1,672	1,591	1,689	1,528	1,133	1,099	1,197	1,184	1,608	2,192	1,109	1,442
h1	December	peak	1,125	1,011	1,156	0,901	0,181	0,175	0,185	0,255	0,665	1,687	1,685	1,951	3,319	2,619	1,561	1,416	1,323	1,147	1,336	1,709	1,691	1,669	1,268	1,125
h1	January	weekend	0,613	0,474	0,264	0,114	0,096	0,053	0,074	0,144	0,214	0,675	1,147	0,804	0,661	0,614	0,596	0,609	0,577	0,506	0,660	0,345	0,544	0,777	0,685	0,604
h1	February	weekend	0,616	0,503	0,308	0,226	0,127	0,066	0,097	0,340	0,480	0,547	0,436	0,482	0,472	0,656	0,559	0,526	0,411	0,484	0,577	0,783	0,962	1,002	0,954	0,704
h1	March	weekend	0,580	0,524	0,270	0,133	0,110	0,120	0,134	0,181	0,182	0,402	0,381	0,192	0,376	0,573	0,620	0,644	0,591	0,534	0,514	0,328	0,463	0,849	0,822	0,719
h1	April	weekend	0,488	0,187	0,095	0,091	0,125	0,122	0,183	0,209	0,243	0,210	0,128	0,284	0,482	0,861	0,709	0,648	0,420	0,468	0,377	0,330	0,492	0,805	0,678	0,632
h1	May	weekend	0,284	0,202	0,164	0,146	0,167	0,167	0,325	0,395	0,374	0,494	0,534	0,468	0,680	0,534	0,362	0,301	0,298	0,349	0,303	0,206	0,280	0,452	0,396	0,301
h1	June	weekend	0,234	0,183	0,181	0,171	0,176	0,191	0,347	0,322	0,358	0,387	0,483	0,370	0,411	0,563	0,348	0,445	0,322	0,280	0,261	0,270	0,272	0,422	0,310	0,292
h1	July	weekend	0,325	0,311	0,239	0,200	0,225	0,293	0,378	0,393	0,474	0,335	0,315	0,268	0,466	0,598	0,354	0,360	0,357	0,388	0,362	0,313	0,296	0,442	0,333	0,384
h1	August	weekend	0,457	0,301	0,217	0,217	0,216	0,212	0,291	0,455	0,359	0,305	0,375	0,427	0,544	0,500	0,332	0,420	0,368	0,329	0,359	0,314	0,414	0,437	0,412	0,327
h1	September	weekend	0,249	0,185	0,165	0,167	0,155	0,172	0,217	0,317	0,216	0,319	0,458	0,358	0,358	0,385	0,358	0,411	0,316	0,264	0,324	0,385	0,529	0,535	0,340	0,298
h1	October	weekend	0,298	0,223	0,200	0,143	0,164	0,147	0,206	0,214	0,251	0,244	0,220	0,260	0,454	0,476	0,476	0,556	0,330	0,280	0,358	0,452	0,641	0,398	0,397	0,309
h1	November	weekend	0,615	0,543	0,216	0,103	0,131	0,123	0,140	0,228	0,144	0,175	0,482	0,469	0,448	0,493	0,554	0,436	0,351	0,355	0,386	0,486	0,652	0,710	0,584	0,555
h1	December	weekend	0,529	0,380	0,172	0,116	0,107	0,111	0,097	0,154	0,147	0,218	0,438	0,482	0,395	0,445	0,694	0,547	0,485	0,381	0,757	0,779	0,826	0,861	0,595	0,558

Electricity consumption – Guadalajara

Household	Month	Period	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
h1	January	week	0,371	0,283	0,277	0,256	0,267	0,262	0,228	0,288	1,022	1,295	1,241	1,198	0,836	1,142	0,768	0,608	0,663	0,585	0,616	0,744	0,673	0,599	0,655	0,602
h1	February	week	0,356	0,334	0,224	0,221	0,246	0,250	0,219	0,444	0,877	1,492	0,833	0,580	1,019	1,128	1,109	0,901	0,899	0,672	0,745	0,808	0,905	0,745	0,624	0,506
h1	March	week	0,469	0,271	0,220	0,224	0,220	0,226	0,234	0,505	0,756	0,969	0,778	0,584	0,751	0,986	1,013	0,577	0,612	0,482	0,316	0,470	0,715	0,858	0,516	0,548
h1	April	week	0,237	0,220	0,208	0,220	0,214	0,218	0,322	0,789	0,869	0,656	0,614	0,929	0,764	0,963	0,555	0,596	0,490	0,461	0,382	0,601	0,773	0,558	0,523	0,481
h1	May	week	0,246	0,231	0,229	0,215	0,239	0,229	0,406	0,508	0,689	0,510	0,652	0,784	0,715	0,802	0,493	0,566	0,522	0,378	0,349	0,398	0,639	0,448	0,445	0,312

h1	June	week	0,250	0,231	0,230	0,228	0,232	0,255	0,360	0,425	0,448	0,506	0,526	0,573	0,615	0,696	0,759	0,687	0,473	0,509	0,458	0,547	0,518	0,436	0,391	0,326
h1	July	week	0,345	0,276	0,249	0,251	0,257	0,274	0,362	0,472	0,581	0,639	0,642	0,681	0,664	0,785	0,741	0,788	0,722	0,674	0,537	0,503	0,603	0,628	0,701	0,550
h1	August	week	0,282	0,256	0,262	0,243	0,258	0,252	0,349	0,466	0,645	0,791	0,831	0,632	0,615	0,811	0,566	1,001	0,707	0,530	0,453	0,435	0,496	0,448	0,532	0,381
h1	September	week	0,271	0,265	0,269	0,260	0,271	0,278	0,398	0,431	0,494	0,509	0,614	0,686	0,645	0,721	0,643	0,731	0,519	0,456	0,520	0,533	0,557	0,432	0,397	0,306
h1	October	week	0,267	0,232	0,219	0,228	0,221	0,252	0,310	0,517	0,728	0,660	0,503	0,624	0,805	0,749	0,882	0,783	0,599	0,509	0,539	0,642	0,595	0,517	0,524	0,416
h1	November	week	0,289	0,227	0,217	0,223	0,212	0,217	0,218	0,316	0,593	0,730	0,461	0,495	0,739	0,611	0,715	0,493	0,499	0,517	0,453	0,529	0,566	0,614	0,537	0,459
h1	December	week	0,330	0,270	0,231	0,216	0,232	0,230	0,225	0,310	0,731	1,076	0,726	0,521	0,432	0,725	1,021	0,760	0,823	0,572	0,617	0,687	0,762	0,722	0,477	0,511
h1	January	peak	1,515	0,624	0,727	0,654	0,634	0,577	0,579	1,034	2,566	2,909	3,332	3,512	3,554	2,784	2,468	2,831	2,042	1,944	1,896	2,553	1,480	1,795	1,684	2,209
h1	February	peak	1,143	1,428	0,327	0,273	0,678	0,624	0,733	1,554	1,898	3,347	2,151	2,729	3,016	3,570	3,193	2,702	2,659	1,936	2,001	1,833	2,234	2,216	1,899	1,561
h1	March	peak	1,492	0,657	0,270	0,293	0,292	0,371	0,630	1,268	1,980	2,279	2,090	2,247	1,988	3,735	2,351	1,676	2,458	1,709	0,568	1,244	1,798	2,449	1,152	1,789
h1	April	peak	0,435	0,270	0,259	0,258	0,269	0,296	1,047	2,878	1,770	2,043	1,800	2,474	2,202	2,472	1,253	2,067	1,566	1,613	2,104	2,315	1,478	1,319	2,012	1,370
h1	May	peak	0,704	0,288	0,281	0,263	0,289	0,373	0,917	0,959	2,465	2,045	2,674	3,233	1,772	1,776	1,585	1,607	2,354	2,599	1,033	0,828	1,326	1,039	1,054	1,085
h1	June	peak	0,384	0,320	0,355	0,366	0,375	0,794	1,195	1,050	1,488	2,000	2,089	2,809	1,984	2,376	2,110	1,925	1,778	2,068	1,482	2,361	1,304	1,452	1,225	1,214
h1	July	peak	1,791	0,611	0,326	0,316	0,317	0,349	0,850	1,124	1,592	2,092	1,739	2,084	2,323	1,807	1,613	2,642	1,761	2,126	1,643	1,475	2,056	1,672	1,990	1,295
h1	August	peak	1,454	0,387	0,356	0,352	0,317	0,413	0,590	1,877	1,790	2,257	1,869	2,464	1,550	2,113	1,268	2,090	1,395	2,044	2,228	1,936	1,467	1,640	1,493	1,340
h1	September	peak	0,520	0,560	0,534	0,529	0,524	0,523	0,753	0,944	1,242	1,529	2,305	1,964	1,804	1,998	1,499	1,765	1,773	0,998	1,961	2,106	1,622	0,583	1,365	0,574
h1	October	peak	0,951	0,347	0,256	0,292	0,269	0,397	0,457	1,262	1,982	2,134	2,238	2,337	2,127	2,887	2,501	2,492	1,522	1,344	1,718	1,436	1,271	1,304	1,340	1,468
h1	November	peak	1,219	0,273	0,298	0,324	0,267	0,281	0,278	0,643	1,302	2,521	1,443	3,069	3,370	2,521	2,191	2,090	2,544	1,682	1,158	1,188	1,722	1,317	1,210	0,902
h1	December	peak	0,929	1,224	1,021	0,885	0,352	0,456	0,303	0,912	2,366	2,791	2,311	2,925	2,252	2,615	3,366	2,357	2,198	1,698	2,292	2,696	2,822	1,584	1,434	1,335
h1	January	weekend	0,447	0,257	0,218	0,209	0,215	0,221	0,239	0,448	0,615	1,363	1,291	0,949	1,043	1,196	1,098	0,789	0,732	0,589	0,440	0,569	0,651	0,661	0,763	0,621
h1	February	weekend	0,431	0,332	0,242	0,213	0,221	0,220	0,342	0,440	0,860	1,251	1,170	0,934	0,832	0,892	1,509	1,046	0,765	0,587	0,451	0,608	0,609	0,938	0,641	0,649
h1	March	weekend	0,269	0,283	0,226	0,214	0,214	0,208	0,218	0,313	0,590	1,119	0,758	0,799	0,777	0,626	0,479	0,507	0,533	0,356	0,286	0,360	0,733	0,539	0,470	0,686
h1	April	weekend	0,269	0,211	0,228	0,207	0,217	0,195	0,343	0,422	0,512	0,335	0,316	0,418	0,570	0,650	0,395	0,386	0,373	0,320	0,375	0,418	0,464	0,542	0,410	0,334
h1	May	weekend	0,264	0,228	0,216	0,234	0,203	0,232	0,284	0,409	0,561	0,649	0,618	0,563	0,622	0,551	0,593	0,541	0,526	0,626	0,351	0,337	0,481	0,319	0,372	0,360
h1	June	weekend	0,276	0,261	0,248	0,236	0,260	0,248	0,277	0,288	0,349	0,280	0,315	0,374	0,505	0,505	0,549	0,771	0,732	0,425	0,381	0,377	0,334	0,391	0,336	0,334
h1	July	weekend	0,268	0,271	0,261	0,248	0,256	0,264	0,316	0,405	0,441	0,399	0,530	0,358	0,501	0,624	0,584	1,041	0,508	0,597	0,447	0,476	0,459	0,498	0,541	0,612
h1	August	weekend	0,419	0,271	0,247	0,239	0,232	0,253	0,329	0,542	0,580	0,635	0,458	0,721	0,822	0,644	0,614	0,808	0,782	0,611	0,775	0,458	0,504	0,665	0,538	0,438
h1	September	weekend	0,286	0,272	0,254	0,271	0,273	0,279	0,355	0,442	0,609	0,475	0,315	0,398	0,434	0,546	0,620	0,587	0,669	0,361	0,577	0,545	0,612	0,395	0,511	0,329
h1	October	weekend	0,234	0,213	0,222	0,210	0,227	0,220	0,342	0,523	0,622	0,559	0,457	0,756	0,688	0,473	0,523	0,429	0,393	0,327	0,442	0,409	0,550	0,420	0,339	0,396
h1	November	weekend	0,384	0,229	0,206	0,216	0,210	0,199	0,216	0,241	0,456	0,610	0,565	0,320	0,282	0,371	0,746	0,448	0,725	0,467	0,363	0,442	0,373	0,464	0,351	0,349
h1	December	weekend	0,430	0,306	0,323	0,315	0,218	0,231	0,229	0,258	0,526	1,445	0,676	0,267	0,429	1,123	1,411	0,806	1,140	0,777	0,774	0,591	0,524	0,626	0,790	0,479

Normalized electricity consumption – Guadalajara

Household	Month	Period	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
h1	January	week	0,261	0,199	0,195	0,180	0,188	0,184	0,160	0,202	0,717	0,909	0,871	0,841	0,587	0,802	0,539	0,427	0,465	0,411	0,432	0,522	0,473	0,420	0,460	0,423
h1	February	week	0,250	0,234	0,157	0,155	0,172	0,176	0,154	0,312	0,616	1,047	0,585	0,407	0,715	0,792	0,778	0,632	0,631	0,472	0,523	0,567	0,635	0,523	0,438	0,355
h1	March	week	0,329	0,190	0,155	0,157	0,154	0,159	0,164	0,355	0,530	0,680	0,546	0,410	0,527	0,692	0,711	0,405	0,430	0,339	0,222	0,330	0,502	0,602	0,362	0,385
h1	April	week	0,166	0,154	0,146	0,154	0,150	0,153	0,226	0,554	0,610	0,461	0,431	0,652	0,536	0,676	0,389	0,418	0,344	0,323	0,268	0,422	0,542	0,391	0,367	0,338
h1	May	week	0,173	0,162	0,161	0,151	0,168	0,161	0,285	0,356	0,484	0,358	0,457	0,550	0,502	0,563	0,346	0,397	0,367	0,265	0,245	0,280	0,449	0,314	0,313	0,219
h1	June	week	0,176	0,162	0,162	0,160	0,163	0,179	0,253	0,298	0,315	0,355	0,369	0,402	0,432	0,488	0,533	0,482	0,332	0,357	0,322	0,384	0,363	0,306	0,275	0,229
h1	July	week	0,242	0,194	0,175	0,176	0,181	0,192	0,254	0,331	0,408	0,448	0,451	0,478	0,466	0,551	0,520	0,553	0,507	0,473	0,377	0,353	0,423	0,441	0,492	0,386
h1	August	week	0,198	0,180	0,184	0,171	0,181	0,177	0,245	0,327	0,453	0,555	0,583	0,444	0,432	0,569	0,398	0,703	0,496	0,372	0,318	0,306	0,348	0,315	0,373	0,267
h1	September	week	0,190	0,186	0,189	0,183	0,190	0,195	0,279	0,302	0,347	0,357	0,431	0,481	0,453	0,506	0,451	0,513	0,364	0,320	0,365	0,374	0,391	0,304	0,279	0,214
h1	October	week	0,187	0,163	0,154	0,160	0,155	0,177	0,217	0,363	0,511	0,463	0,353	0,438	0,565	0,525	0,619	0,550	0,420	0,357	0,379	0,451	0,418	0,363	0,368	0,292
h1	November	week	0,203	0,159	0,152	0,157	0,149	0,152	0,153	0,222	0,416	0,512	0,323	0,347	0,519	0,429	0,502	0,346	0,351	0,363	0,318	0,371	0,398	0,431	0,377	0,323
h1	December	week	0,232	0,190	0,162	0,151	0,163	0,162	0,158	0,218	0,513	0,755	0,510	0,365	0,304	0,509	0,717	0,534	0,578	0,402	0,433	0,482	0,535	0,507	0,335	0,359
h1	January	peak	1,064	0,438	0,510	0,459	0,445	0,405	0,406	0,726	1,801	2,042	2,339	2,465	2,495	1,954	1,733	1,987	1,433	1,365	1,331	1,792	1,039	1,260	1,182	1,551
h1	February	peak	0,802	1,002	0,230	0,192	0,476	0,438	0,515	1,091	1,332	2,350	1,510	1,916	2,117	2,506	2,241	1,897	1,867	1,359	1,405	1,287	1,568	1,556	1,333	1,096
h1	March	peak	1,047	0,461	0,190	0,206	0,205	0,260	0,442	0,890	1,390	1,600	1,467	1,577	1,396	2,622	1,650	1,177	1,726	1,200	0,399	0,873	1,262	1,719	0,809	1,256
h1	April	peak	0,305	0,190	0,182	0,181	0,189	0,208	0,735	2,020	1,243	1,434	1,264	1,737	1,546	1,735	0,880	1,451	1,099	1,132	1,477	1,625	1,038	0,926	1,412	0,962
h1	May	peak	0,494	0,202	0,197	0,185	0,203	0,262	0,644	0,673	1,730	1,436	1,877	2,270	1,244	1,247	1,113	1,128	1,653	1,824	0,725	0,581	0,931	0,729	0,740	0,762
h1	June	peak	0,270	0,225	0,249	0,257	0,263	0,557	0,839	0,737	1,045	1,404	1,466	1,972	1,393	1,668	1,481	1,351	1,248	1,452	1,040	1,657	0,915	1,019	0,860	0,852
h1	July	peak	1,257	0,429	0,229	0,222	0,223	0,245	0,597	0,789	1,118	1,469	1,221	1,463	1,631	1,269	1,132	1,855	1,236	1,492	1,153	1,035	1,443	1,174	1,397	0,909
h1	August	peak	1,021	0,272	0,250	0,247	0,223	0,290	0,414	1,318	1,257	1,584	1,312	1,730	1,088	1,483	0,890	1,467	0,979	1,435	1,564	1,359	1,030	1,151	1,048	0,941
h1	September	peak	0,365	0,393	0,375	0,371	0,368	0,367	0,529	0,663	0,872	1,073	1,618	1,379	1,266	1,403	1,052	1,239	1,245	0,701	1,377	1,478	1,139	0,409	0,958	0,403
h1	October	peak	0,668	0,244	0,180	0,205	0,189	0,279	0,321	0,886	1,391	1,498	1,571	1,641	1,493	2,027	1,756	1,749	1,068	0,943	1,206	1,008	0,892	0,915	0,941	1,031
h1	November	peak	0,856	0,192	0,209	0,227	0,187	0,197	0,195	0,451	0,914	1,770	1,013	2,154	2,366	1,770	1,538	1,467	1,786	1,181	0,813	0,834	1,209	0,925	0,849	0,633
h1	December	peak	0,652	0,859	0,717	0,621	0,247	0,320	0,213	0,640	1,661	1,959	1,622	2,053	1,581	1,836	2,363	1,655	1,543	1,192	1,609	1,893	1,981	1,112	1,007	0,937
h1	January	weekend	0,314	0,180	0,153	0,146	0,151	0,155	0,168	0,314	0,431	0,957	0,907	0,666	0,732	0,840	0,771	0,554	0,514	0,413	0,309	0,400	0,457	0,464	0,536	0,436
h1	February	weekend	0,302	0,233	0,170	0,150	0,155	0,155	0,240	0,309	0,604	0,878	0,821	0,656	0,584	0,626	1,059	0,734	0,537	0,412	0,317	0,427	0,428	0,659	0,450	0,456
h1	March	weekend	0,189	0,198	0,159	0,150	0,150	0,146	0,153	0,220	0,414	0,785	0,532	0,561	0,546	0,439	0,336	0,356	0,374	0,250	0,201	0,253	0,514	0,379	0,330	0,481
h1	April	weekend	0,189	0,148	0,160	0,146	0,152	0,137	0,241	0,296	0,359	0,235	0,222	0,294	0,400	0,456	0,277	0,271	0,262	0,224	0,263	0,293	0,325	0,381	0,288	0,234
h1	May	weekend	0,185	0,160	0,152	0,164	0,143	0,163	0,199	0,287	0,394	0,456	0,433	0,395	0,437	0,387	0,416	0,380	0,369	0,439	0,247	0,237	0,338	0,224	0,261	0,253
h1	June	weekend	0,193	0,183	0,174	0,166	0,183	0,174	0,194	0,202	0,245	0,197	0,221	0,263	0,355	0,354	0,386	0,541	0,514	0,298	0,267	0,265	0,234	0,274	0,236	0,234
h1	July	weekend	0,188	0,190	0,183	0,174	0,180	0,185	0,222	0,284	0,310	0,280	0,372	0,251	0,351	0,438	0,410	0,731	0,356	0,419	0,314	0,334	0,322	0,350	0,380	0,430
h1	August	weekend	0,294	0,190	0,174	0,168	0,163	0,177	0,231	0,380	0,407	0,446	0,322	0,506	0,577	0,452	0,431	0,568	0,549	0,429	0,544	0,322	0,353	0,467	0,377	0,307
h1	September	weekend	0,200	0,191	0,179	0,190	0,192	0,196	0,249	0,310	0,427	0,334	0,221	0,279	0,304	0,383	0,435	0,412	0,470	0,253	0,405	0,383	0,429	0,277	0,359	0,231
h1	October	weekend	0,164	0,150	0,156	0,147	0,159	0,154	0,240	0,367	0,437	0,392	0,321	0,531	0,483	0,332	0,367	0,301	0,276	0,229	0,310	0,287	0,386	0,295	0,238	0,278

h1	November	weekend	0,269	0,161	0,145	0,152	0,148	0,140	0,152	0,169	0,320	0,428	0,397	0,225	0,198	0,260	0,524	0,315	0,509	0,328	0,255	0,310	0,262	0,325	0,246	0,245
h1	December	weekend	0,302	0,215	0,227	0,221	0,153	0,162	0,160	0,181	0,369	1,014	0,474	0,188	0,301	0,789	0,990	0,566	0,800	0,545	0,543	0,415	0,368	0,439	0,555	0,336

Electricity consumption – Oviedo

Household	Month	Period	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
h1	January	week	0,127	0,065	0,043	0,045	0,039	0,042	0,038	0,035	0,074	0,051	0,053	0,046	0,066	0,062	0,071	0,081	0,101	0,055	0,081	0,150	0,115	0,256	0,263	0,190
h1	February	week	0,120	0,048	0,041	0,036	0,040	0,030	0,036	0,035	0,061	0,070	0,049	0,075	0,043	0,053	0,071	0,073	0,036	0,030	0,044	0,131	0,145	0,217	0,252	0,147
h1	March	week	0,201	0,057	0,049	0,039	0,034	0,033	0,039	0,044	0,096	0,064	0,105	0,197	0,128	0,072	0,080	0,142	0,075	0,060	0,075	0,069	0,066	0,171	0,231	0,149
h1	April	week	0,077	0,111	0,055	0,047	0,044	0,043	0,052	0,091	0,061	0,051	0,075	0,051	0,071	0,062	0,071	0,143	0,098	0,082	0,067	0,069	0,177	0,318	0,200	0,125
h1	May	week	0,080	0,051	0,054	0,049	0,055	0,040	0,051	0,111	0,081	0,139	0,102	0,177	0,110	0,082	0,230	0,176	0,048	0,047	0,057	0,156	0,219	0,376	0,299	0,103
h1	June	week	0,057	0,092	0,054	0,050	0,055	0,058	0,053	0,078	0,064	0,054	0,050	0,054	0,061	0,051	0,046	0,049	0,051	0,052	0,066	0,055	0,126	0,242	0,138	0,149
h1	July	week	0,078	0,064	0,060	0,055	0,054	0,062	0,055	0,120	0,066	0,086	0,090	0,094	0,054	0,055	0,059	0,058	0,055	0,056	0,062	0,081	0,192	0,235	0,398	0,125
h1	August	week	0,140	0,061	0,050	0,049	0,056	0,054	0,051	0,082	0,050	0,075	0,069	0,093	0,106	0,059	0,084	0,064	0,076	0,070	0,068	0,069	0,158	0,203	0,188	0,121
h1	September	week	0,066	0,065	0,051	0,044	0,057	0,065	0,045	0,093	0,100	0,095	0,104	0,077	0,061	0,055	0,061	0,077	0,094	0,069	0,133	0,076	0,202	0,296	0,243	0,123
h1	October	week	0,087	0,059	0,051	0,057	0,045	0,045	0,054	0,109	0,096	0,115	0,089	0,113	0,142	0,083	0,060	0,063	0,066	0,056	0,050	0,082	0,230	0,314	0,498	0,279
h1	November	week	0,158	0,067	0,049	0,052	0,040	0,040	0,043	0,043	0,085	0,065	0,066	0,132	0,118	0,065	0,125	0,112	0,099	0,047	0,066	0,073	0,078	0,200	0,307	0,210
h1	December	week	0,158	0,072	0,084	0,043	0,034	0,039	0,037	0,035	0,096	0,053	0,078	0,091	0,113	0,136	0,079	0,073	0,075	0,073	0,058	0,093	0,064	0,131	0,255	0,162
h1	January	peak	0,464	0,576	0,180	0,204	0,106	0,119	0,111	0,118	0,212	0,275	0,240	0,605	0,714	1,460	2,167	2,279	2,159	1,556	0,955	1,160	0,657	0,933	2,202	0,575
h1	February	peak	1,082	1,657	0,116	0,099	0,093	0,043	0,114	0,066	0,172	0,509	0,276	0,825	0,240	0,292	0,588	0,729	0,456	0,072	0,280	1,651	1,897	1,451	1,863	2,309
h1	March	peak	2,311	0,377	0,193	0,124	0,100	0,053	0,114	0,175	0,385	0,225	0,746	1,855	2,093	0,310	0,885	2,098	0,731	0,440	0,633	0,599	0,356	0,599	1,099	0,491
h1	April	peak	0,455	0,517	0,123	0,118	0,116	0,072	0,172	0,171	0,186	0,487	0,612	2,363	0,598	0,212	1,147	2,206	1,108	0,782	0,782	0,472	1,483	1,918	0,648	0,473
h1	May	peak	0,548	0,094	0,119	0,106	0,125	0,071	0,124	0,411	0,228	0,493	0,844	2,159	1,305	0,546	2,276	1,887	0,158	1,395	0,244	1,959	1,607	1,670	1,874	0,238
h1	June	peak	0,129	0,481	0,115	0,117	0,116	0,165	0,145	0,650	0,185	0,119	0,116	0,093	0,117	0,259	0,370	0,079	0,119	2,253	1,311	0,373	0,778	1,909	0,400	0,488
h1	July	peak	0,429	0,474	0,122	0,094	0,072	0,135	0,098	0,322	0,280	0,443	0,594	0,936	0,113	0,077	0,120	0,115	0,116	0,115	0,118	0,348	1,569	1,807	1,874	0,486
h1	August	peak	1,649	0,358	0,167	0,079	0,118	0,110	0,086	0,206	0,128	0,267	0,627	0,855	1,188	0,133	0,652	0,231	0,222	0,211	0,201	0,198	1,633	2,111	1,207	0,599
h1	September	peak	0,127	0,127	0,116	0,067	0,119	0,248	0,090	0,309	0,418	0,448	0,818	0,602	0,187	0,204	0,241	0,443	0,535	0,313	1,664	0,391	0,552	1,755	1,084	0,537
h1	October	peak	0,510	0,502	0,109	0,121	0,090	0,121	0,136	0,435	0,429	0,492	0,507	1,277	2,018	0,669	0,446	0,399	0,277	0,377	1,582	0,562	2,483	1,421	2,086	1,434
h1	November	peak	0,575	0,465	0,113	0,118	0,114	0,062	0,064	0,121	0,664	0,657	0,717	1,733	1,374	2,316	1,111	0,988	1,129	1,570	0,395	0,264	0,268	1,110	2,209	1,378
h1	December	peak	0,630	0,550	0,584	0,098	0,110	0,076	0,074	0,075	0,185	0,159	0,821	0,619	1,384	1,660	2,148	0,853	0,879	0,482	0,451	1,846	1,582	1,313	1,413	0,694
h1	January	weekend	0,168	0,116	0,037	0,030	0,033	0,031	0,038	0,029	0,058	0,095	0,056	0,161	0,132	0,260	0,423	0,470	0,331	0,336	0,226	0,115	0,168	0,290	0,381	0,184
h1	February	weekend	0,213	0,238	0,050	0,045	0,028	0,034	0,028	0,033	0,082	0,149	0,128	0,191	0,055	0,064	0,139	0,152	0,106	0,040	0,031	0,098	0,158	0,463	0,665	0,709
h1	March	weekend	0,124	0,087	0,065	0,054	0,042	0,037	0,045	0,034	0,083	0,029	0,056	0,036	0,092	0,072	0,168	0,125	0,045	0,032	0,045	0,110	0,080	0,191	0,243	0,088
h1	April	weekend	0,119	0,111	0,056	0,058	0,038	0,054	0,050	0,082	0,057	0,123	0,182	0,345	0,136	0,069	0,225	0,333	0,168	0,151	0,167	0,146	0,283	0,296	0,193	0,106

h1	May	weekend	0,062	0,054	0,044	0,040	0,044	0,045	0,035	0,116	0,063	0,092	0,081	0,071	0,038	0,044	0,079	0,056	0,056	0,198	0,061	0,081	0,106	0,183	0,202	0,087
h1	June	weekend	0,051	0,054	0,057	0,054	0,043	0,044	0,050	0,163	0,058	0,051	0,049	0,053	0,047	0,068	0,089	0,057	0,073	0,321	0,209	0,091	0,205	0,523	0,112	0,116
h1	July	weekend	0,076	0,118	0,060	0,053	0,061	0,057	0,051	0,104	0,109	0,074	0,059	0,058	0,063	0,057	0,059	0,065	0,060	0,057	0,060	0,065	0,216	0,294	0,081	0,065
h1	August	weekend	0,127	0,085	0,063	0,047	0,060	0,051	0,051	0,058	0,060	0,073	0,118	0,075	0,049	0,059	0,070	0,052	0,057	0,071	0,070	0,048	0,063	0,060	0,064	0,056
h1	September	weekend	0,071	0,062	0,062	0,048	0,049	0,043	0,047	0,108	0,062	0,060	0,053	0,049	0,046	0,054	0,048	0,051	0,089	0,074	0,051	0,096	0,128	0,254	0,200	0,098
h1	October	weekend	0,140	0,108	0,063	0,059	0,061	0,046	0,068	0,089	0,084	0,073	0,081	0,064	0,043	0,052	0,106	0,086	0,059	0,094	0,220	0,106	0,451	0,328	0,174	0,132
h1	November	weekend	0,156	0,060	0,041	0,047	0,053	0,039	0,040	0,045	0,177	0,193	0,165	0,098	0,198	0,330	0,207	0,088	0,080	0,260	0,091	0,078	0,092	0,392	0,572	0,291
h1	December	weekend	0,161	0,082	0,034	0,034	0,048	0,032	0,036	0,033	0,069	0,070	0,077	0,104	0,090	0,069	0,301	0,207	0,073	0,082	0,051	0,295	0,308	0,284	0,226	0,160

Normalized electricity consumption – Oviedo

Household	Month	Period	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
h1	January	week	0,347	0,179	0,118	0,123	0,107	0,117	0,105	0,095	0,204	0,141	0,145	0,127	0,181	0,171	0,194	0,222	0,277	0,150	0,222	0,412	0,315	0,704	0,722	0,521
h1	February	week	0,330	0,130	0,112	0,099	0,110	0,083	0,099	0,095	0,168	0,192	0,134	0,205	0,117	0,146	0,194	0,200	0,100	0,081	0,121	0,360	0,396	0,596	0,691	0,403
h1	March	week	0,551	0,157	0,135	0,108	0,093	0,090	0,106	0,120	0,264	0,176	0,287	0,539	0,352	0,199	0,220	0,389	0,205	0,165	0,206	0,188	0,180	0,469	0,633	0,409
h1	April	week	0,210	0,305	0,152	0,128	0,120	0,119	0,144	0,249	0,168	0,141	0,205	0,139	0,196	0,170	0,194	0,392	0,268	0,224	0,184	0,188	0,486	0,873	0,549	0,343
h1	May	week	0,219	0,140	0,148	0,134	0,150	0,110	0,139	0,304	0,221	0,380	0,278	0,486	0,303	0,224	0,631	0,484	0,132	0,128	0,158	0,429	0,600	1,032	0,821	0,283
h1	June	week	0,156	0,252	0,147	0,138	0,151	0,158	0,144	0,214	0,176	0,149	0,137	0,148	0,169	0,141	0,126	0,133	0,141	0,142	0,180	0,152	0,345	0,663	0,380	0,408
h1	July	week	0,214	0,176	0,164	0,150	0,148	0,170	0,150	0,330	0,182	0,236	0,245	0,259	0,147	0,151	0,161	0,160	0,150	0,154	0,169	0,222	0,526	0,646	1,093	0,342
h1	August	week	0,384	0,168	0,137	0,134	0,153	0,149	0,141	0,225	0,138	0,206	0,190	0,255	0,290	0,161	0,230	0,176	0,208	0,193	0,187	0,189	0,433	0,557	0,516	0,333
h1	September	week	0,181	0,177	0,139	0,122	0,155	0,177	0,124	0,255	0,273	0,262	0,285	0,211	0,166	0,150	0,167	0,212	0,259	0,189	0,364	0,209	0,555	0,811	0,667	0,337
h1	October	week	0,239	0,161	0,140	0,156	0,122	0,123	0,147	0,300	0,262	0,316	0,243	0,310	0,391	0,228	0,166	0,173	0,180	0,154	0,137	0,224	0,630	0,861	1,367	0,766
h1	November	week	0,433	0,185	0,135	0,142	0,111	0,109	0,117	0,117	0,234	0,178	0,181	0,363	0,323	0,178	0,344	0,308	0,272	0,128	0,181	0,199	0,215	0,548	0,842	0,576
h1	December	week	0,434	0,197	0,231	0,118	0,092	0,107	0,101	0,096	0,264	0,146	0,215	0,249	0,310	0,373	0,218	0,200	0,205	0,200	0,159	0,256	0,176	0,358	0,701	0,445
h1	January	peak	1,273	1,580	0,494	0,560	0,291	0,326	0,304	0,324	0,582	0,754	0,658	1,660	1,959	4,005	5,944	6,251	5,922	4,268	2,620	3,182	1,802	2,559	6,040	1,577
h1	February	peak	2,968	4,545	0,318	0,272	0,255	0,118	0,313	0,181	0,472	1,396	0,757	2,263	0,658	0,801	1,613	2,000	1,251	0,197	0,768	4,529	5,203	3,980	5,110	6,334
h1	March	peak	6,339	1,034	0,529	0,340	0,274	0,145	0,313	0,480	1,056	0,617	2,046	5,088	5,741	0,850	2,428	5,755	2,005	1,207	1,736	1,643	0,977	1,643	3,015	1,347
h1	April	peak	1,248	1,418	0,337	0,324	0,318	0,197	0,472	0,469	0,510	1,336	1,679	6,482	1,640	0,582	3,146	6,051	3,039	2,145	2,145	1,295	4,068	5,261	1,777	1,297
h1	May	peak	1,503	0,258	0,326	0,291	0,343	0,195	0,340	1,127	0,625	1,352	2,315	5,922	3,580	1,498	6,243	5,176	0,433	3,826	0,669	5,374	4,408	4,581	5,140	0,653
h1	June	peak	0,354	1,319	0,315	0,321	0,318	0,453	0,398	1,783	0,507	0,326	0,318	0,255	0,321	0,710	1,015	0,217	0,326	6,180	3,596	1,023	2,134	5,236	1,097	1,339
h1	July	peak	1,177	1,300	0,335	0,258	0,197	0,370	0,269	0,883	0,768	1,215	1,629	2,567	0,310	0,211	0,329	0,315	0,318	0,315	0,324	0,955	4,304	4,957	5,140	1,333
h1	August	peak	4,523	0,982	0,458	0,217	0,324	0,302	0,236	0,565	0,351	0,732	1,720	2,345	3,259	0,365	1,788	0,634	0,609	0,579	0,551	0,543	4,479	5,790	3,311	1,643
h1	September	peak	0,348	0,348	0,318	0,184	0,326	0,680	0,247	0,848	1,147	1,229	2,244	1,651	0,513	0,560	0,661	1,215	1,468	0,859	4,564	1,073	1,514	4,814	2,973	1,473
h1	October	peak	1,399	1,377	0,299	0,332	0,247	0,332	0,373	1,193	1,177	1,350	1,391	3,503	5,535	1,835	1,223	1,094	0,760	1,034	4,339	1,542	6,811	3,898	5,722	3,933

h1	November	peak	1,577	1,275	0,310	0,324	0,313	0,170	0,176	0,332	1,821	1,802	1,967	4,754	3,769	6,353	3,047	2,710	3,097	4,307	1,083	0,724	0,735	3,045	6,059	3,780
h1	December	peak	1,728	1,509	1,602	0,269	0,302	0,208	0,203	0,206	0,507	0,436	2,252	1,698	3,796	4,553	5,892	2,340	2,411	1,322	1,237	5,064	4,339	3,602	3,876	1,904
h1	January	weekend	0,462	0,318	0,101	0,083	0,091	0,086	0,104	0,080	0,159	0,260	0,153	0,442	0,362	0,713	1,160	1,290	0,908	0,921	0,619	0,316	0,462	0,796	1,045	0,505
h1	February	weekend	0,583	0,652	0,138	0,123	0,077	0,092	0,077	0,091	0,225	0,408	0,352	0,524	0,151	0,175	0,382	0,416	0,290	0,109	0,085	0,268	0,433	1,269	1,825	1,945
h1	March	weekend	0,340	0,238	0,178	0,148	0,115	0,101	0,123	0,094	0,226	0,081	0,155	0,099	0,253	0,197	0,461	0,343	0,124	0,088	0,123	0,300	0,219	0,525	0,666	0,242
h1	April	weekend	0,327	0,304	0,153	0,159	0,105	0,147	0,136	0,225	0,155	0,336	0,500	0,946	0,374	0,189	0,617	0,914	0,461	0,413	0,457	0,402	0,775	0,813	0,529	0,290
h1	May	weekend	0,170	0,147	0,119	0,111	0,120	0,122	0,095	0,318	0,171	0,253	0,222	0,195	0,103	0,120	0,215	0,154	0,153	0,544	0,167	0,221	0,292	0,502	0,554	0,238
h1	June	weekend	0,139	0,148	0,155	0,148	0,117	0,121	0,137	0,446	0,158	0,140	0,135	0,146	0,128	0,187	0,245	0,156	0,199	0,880	0,573	0,249	0,562	1,436	0,306	0,318
h1	July	weekend	0,209	0,323	0,165	0,146	0,166	0,156	0,140	0,286	0,300	0,204	0,162	0,159	0,173	0,157	0,162	0,178	0,163	0,158	0,164	0,177	0,592	0,807	0,223	0,178
h1	August	weekend	0,348	0,234	0,173	0,128	0,163	0,141	0,141	0,158	0,164	0,199	0,325	0,206	0,135	0,161	0,192	0,142	0,158	0,194	0,191	0,132	0,172	0,165	0,176	0,154
h1	September	weekend	0,194	0,169	0,169	0,133	0,135	0,117	0,130	0,296	0,171	0,165	0,145	0,133	0,127	0,147	0,131	0,140	0,243	0,204	0,139	0,263	0,350	0,697	0,548	0,270
h1	October	weekend	0,384	0,296	0,174	0,160	0,168	0,127	0,186	0,245	0,232	0,200	0,222	0,175	0,119	0,142	0,292	0,235	0,160	0,257	0,602	0,289	1,237	0,899	0,478	0,361
h1	November	weekend	0,429	0,164	0,113	0,130	0,145	0,106	0,110	0,124	0,485	0,529	0,453	0,268	0,544	0,905	0,568	0,240	0,219	0,713	0,250	0,214	0,252	1,075	1,568	0,797
h1	December	weekend	0,442	0,225	0,094	0,094	0,131	0,087	0,099	0,090	0,189	0,192	0,210	0,284	0,245	0,189	0,826	0,567	0,199	0,224	0,141	0,810	0,845	0,780	0,620	0,440

7.4 Apendix D: Analytical results by geography

Grid Supply Energy Balance – Córdoba (May week)

Hour	Demand	Electricity Purchase	Wholesale price	Retail price
1:00	0,255	0,255	0,024	0,128
2:00	0,197	0,197	0,021	0,123
3:00	0,162	0,162	0,019	0,119
4:00	0,167	0,167	0,016	0,115
5:00	0,164	0,164	0,016	0,115
6:00	0,168	0,168	0,019	0,119
7:00	0,231	0,231	0,023	0,126
8:00	0,237	0,237	0,031	0,139
9:00	0,299	0,299	0,034	0,143
10:00	0,213	0,213	0,033	0,141

11:00	0,235	0,235	0,032	0,140
12:00	0,346	0,346	0,032	0,140
13:00	0,644	0,644	0,031	0,138
14:00	0,542	0,542	0,028	0,134
15:00	0,298	0,298	0,026	0,130
16:00	0,275	0,275	0,024	0,128
17:00	0,281	0,281	0,024	0,127
18:00	0,223	0,223	0,026	0,130
19:00	0,212	0,212	0,029	0,136
20:00	0,227	0,227	0,033	0,142
21:00	0,234	0,234	0,032	0,141
22:00	0,357	0,357	0,032	0,140
23:00	0,279	0,279	0,034	0,144
0:00	0,303	0,303	0,030	0,138

Grid Integrated Energy Balance – Córdoba (May week)

Hour	Demand	Electricity Purchase	Self Consumption	Export	PV Generation
1:00	0,255	0,255	0,000	0,000	0,000
2:00	0,197	0,197	0,000	0,000	0,000
3:00	0,162	0,162	0,000	0,000	0,000
4:00	0,167	0,167	0,000	0,000	0,000
5:00	0,164	0,164	0,000	0,000	0,000
6:00	0,168	0,168	0,000	0,000	0,000
7:00	0,231	0,030	0,201	0,000	0,201
8:00	0,237	0,000	0,237	0,673	0,910
9:00	0,299	0,000	0,299	1,431	1,731
10:00	0,213	0,000	0,213	2,304	2,517
11:00	0,235	0,000	0,235	3,166	3,400
12:00	0,346	0,000	0,346	3,654	4,001
13:00	0,644	0,000	0,644	3,603	4,247
14:00	0,542	0,000	0,542	3,650	4,192

15:00	0,298	0,000	0,298	3,753	4,050
16:00	0,275	0,000	0,275	3,318	3,594
17:00	0,281	0,000	0,281	2,632	2,912
18:00	0,223	0,000	0,223	1,908	2,131
19:00	0,212	0,000	0,212	1,061	1,272
20:00	0,227	0,000	0,227	0,227	0,453
21:00	0,234	0,180	0,054	0,000	0,054
22:00	0,357	0,357	0,000	0,000	0,000
23:00	0,279	0,279	0,000	0,000	0,000
0:00	0,303	0,303	0,000	0,000	0,000

Grid Integrated Energy Balance – Córdoba (December peak)

Hour	Demand	Electricity Purchase	Self Consumption	Export	PV Generation	Wholesale price	Retail price
1:00	1,125	1,125	0,000	0,000	0,000	0,048	0,165
2:00	1,011	1,011	0,000	0,000	0,000	0,047	0,164
3:00	1,156	1,156	0,000	0,000	0,000	0,044	0,159
4:00	0,901	0,901	0,000	0,000	0,000	0,038	0,150
5:00	0,181	0,181	0,000	0,000	0,000	0,035	0,146
6:00	0,175	0,175	0,000	0,000	0,000	0,038	0,149
7:00	0,185	0,185	0,000	0,000	0,000	0,048	0,165
8:00	0,255	0,255	0,000	0,000	0,000	0,063	0,189
9:00	0,665	0,537	0,128	0,000	0,128	0,066	0,193
10:00	1,687	1,106	0,581	0,000	0,581	0,066	0,194
11:00	1,685	0,472	1,213	0,000	1,213	0,067	0,195
12:00	1,951	0,142	1,809	0,000	1,809	0,059	0,183
13:00	3,319	1,149	2,170	0,000	2,170	0,058	0,181
14:00	2,619	0,401	2,218	0,000	2,218	0,054	0,175
15:00	1,561	0,000	1,561	0,461	2,022	0,055	0,176
16:00	1,416	0,000	1,416	0,122	1,538	0,060	0,185

17:00	1,323	0,453	0,870	0,000	0,870	0,065	0,192
18:00	1,147	0,858	0,289	0,000	0,289	0,069	0,199
19:00	1,336	1,304	0,032	0,000	0,032	0,079	0,214
20:00	1,709	1,709	0,000	0,000	0,000	0,077	0,211
21:00	1,691	1,691	0,000	0,000	0,000	0,061	0,186
22:00	1,669	1,669	0,000	0,000	0,000	0,055	0,176
23:00	1,268	1,268	0,000	0,000	0,000	0,056	0,177
0:00	1,125	1,125	0,000	0,000	0,000	0,054	0,175

Grid Defection Energy Balance – Córdoba (May week)

Hour	Demand	Self Consumption	Non Used	PV Generation	Battery Storage Discharge	Battery Storage Charge
1:00	0,255	0,000	0,000	0,000	0,255	0,000
2:00	0,197	0,000	0,000	0,000	0,197	0,000
3:00	0,162	0,000	0,000	0,000	0,162	0,000
4:00	0,167	0,000	0,000	0,000	0,167	0,000
5:00	0,164	0,000	0,000	0,000	0,164	0,000
6:00	0,168	0,000	0,000	0,000	0,168	0,000
7:00	0,231	0,234	0,268	0,501	0,000	0,003
8:00	0,237	0,240	2,034	2,275	0,000	0,003
9:00	0,299	0,311	4,013	4,324	0,000	0,011
10:00	0,213	0,213	6,075	6,288	0,000	0,000
11:00	0,235	0,235	8,260	8,495	0,000	0,000
12:00	0,346	0,346	9,648	9,994	0,000	0,000
13:00	0,644	0,652	9,958	10,610	0,000	0,009
14:00	0,542	0,542	9,930	10,472	0,000	0,000
15:00	0,298	0,298	9,821	10,119	0,000	0,000
16:00	0,275	0,284	8,694	8,978	0,000	0,009
17:00	0,281	0,281	6,995	7,276	0,000	0,000
18:00	0,223	0,223	5,101	5,323	0,000	0,000
19:00	0,212	2,533	0,646	3,179	0,000	2,321

20:00	0,227	0,227	0,906	1,133	0,000	0,000
21:00	0,234	0,135	0,000	0,135	0,100	0,000
22:00	0,357	0,000	0,000	0,000	0,357	0,000
23:00	0,279	0,000	0,000	0,000	0,279	0,000
0:00	0,303	0,000	0,000	0,000	0,303	0,000

Grid Defection Energy Balance – Córdoba (December peak)

Hour	Demand	Self Consumption	Non Used	PV Generation	Battery Storage Discharge	Battery Storage Charge
1:00	1,125	0,000	0,000	0,000	1,125	0,000
2:00	1,011	0,000	0,000	0,000	1,011	0,000
3:00	1,156	0,000	0,000	0,000	1,156	0,000
4:00	0,901	0,000	0,000	0,000	0,901	0,000
5:00	0,181	0,000	0,000	0,000	0,181	0,000
6:00	0,175	0,000	0,000	0,000	0,175	0,000
7:00	0,185	0,000	0,000	0,000	0,185	0,000
8:00	0,255	0,000	0,000	0,000	0,255	0,000
9:00	0,665	0,320	0,000	0,320	0,345	0,000
10:00	1,687	1,452	0,000	1,452	0,235	0,000
11:00	1,685	3,031	0,000	3,031	0,000	1,346
12:00	1,951	4,520	0,000	4,520	0,000	2,569
13:00	3,319	5,421	0,000	5,421	0,000	2,102
14:00	2,619	5,540	0,000	5,540	0,000	2,921
15:00	1,561	5,052	0,000	5,052	0,000	3,491
16:00	1,416	3,843	0,000	3,843	0,000	2,427
17:00	1,323	2,174	0,000	2,174	0,000	0,851
18:00	1,147	0,723	0,000	0,723	0,424	0,000
19:00	1,336	0,081	0,000	0,081	1,255	0,000
20:00	1,709	0,000	0,000	0,000	1,709	0,000
21:00	1,691	0,000	0,000	0,000	1,691	0,000

22:00	1,669	0,000	0,000	0,000	1,669	0,000
23:00	1,268	0,000	0,000	0,000	1,268	0,000
0:00	1,125	0,000	0,000	0,000	1,125	0,000

Grid Supply Energy Balance – Guadalajara (May week)

Hour	Demand	Electricity Purchase	Wholesale price	Retail price
1:00	0,246	0,246	0,024	0,128
2:00	0,231	0,231	0,021	0,123
3:00	0,229	0,229	0,019	0,119
4:00	0,215	0,215	0,016	0,115
5:00	0,239	0,239	0,016	0,115
6:00	0,229	0,229	0,019	0,119
7:00	0,406	0,406	0,023	0,126
8:00	0,508	0,508	0,031	0,139
9:00	0,689	0,689	0,034	0,143
10:00	0,510	0,510	0,033	0,141
11:00	0,652	0,652	0,032	0,140
12:00	0,784	0,784	0,032	0,140
13:00	0,715	0,715	0,031	0,138
14:00	0,802	0,802	0,028	0,134
15:00	0,493	0,493	0,026	0,130
16:00	0,566	0,566	0,024	0,128
17:00	0,522	0,522	0,024	0,127
18:00	0,378	0,378	0,026	0,130
19:00	0,349	0,349	0,029	0,136
20:00	0,398	0,398	0,033	0,142
21:00	0,639	0,639	0,032	0,141
22:00	0,448	0,448	0,032	0,140
23:00	0,445	0,445	0,034	0,144
0:00	0,312	0,312	0,030	0,138

Grid Integrated Energy Balance – Guadalajara (May week)

Hour	Demand	Electricity Purchase	Self Consumption	Export	PV Generation
1:00	0,246	0,246	0,000	0,000	0,000
2:00	0,231	0,231	0,000	0,000	0,000
3:00	0,229	0,229	0,000	0,000	0,000
4:00	0,215	0,215	0,000	0,000	0,000
5:00	0,239	0,239	0,000	0,000	0,000
6:00	0,229	0,228	0,001	0,000	0,001
7:00	0,406	0,115	0,292	0,000	0,292
8:00	0,508	0,000	0,508	0,569	1,076
9:00	0,689	0,000	0,689	1,301	1,990
10:00	0,510	0,000	0,510	2,387	2,898
11:00	0,652	0,000	0,652	3,055	3,707
12:00	0,784	0,000	0,784	3,431	4,215
13:00	0,715	0,000	0,715	3,701	4,416
14:00	0,802	0,000	0,802	3,458	4,260
15:00	0,493	0,000	0,493	3,476	3,970
16:00	0,566	0,000	0,566	3,025	3,591
17:00	0,522	0,000	0,522	2,427	2,949
18:00	0,378	0,000	0,378	1,795	2,173
19:00	0,349	0,000	0,349	0,999	1,349
20:00	0,398	0,000	0,398	0,072	0,470
21:00	0,639	0,595	0,044	0,000	0,044
22:00	0,448	0,448	0,000	0,000	0,000
23:00	0,445	0,445	0,000	0,000	0,000
0:00	0,312	0,312	0,000	0,000	0,000

Grid Integrated Energy Balance – Guadalajara (December peak)

Hour	Demand	Electricity Purchase	Self Consumption	Export	PV Generation	Wholesale price	Retail price

1:00	0,929	0,929	0,000	0,000	0,000	0,048	0,165
2:00	1,224	1,224	0,000	0,000	0,000	0,047	0,164
3:00	1,021	1,021	0,000	0,000	0,000	0,044	0,159
4:00	0,885	0,885	0,000	0,000	0,000	0,038	0,150
5:00	0,352	0,352	0,000	0,000	0,000	0,035	0,146
6:00	0,456	0,456	0,000	0,000	0,000	0,038	0,149
7:00	0,303	0,303	0,000	0,000	0,000	0,048	0,165
8:00	0,912	0,912	0,000	0,000	0,000	0,063	0,189
9:00	2,366	2,253	0,113	0,000	0,113	0,066	0,193
10:00	2,791	2,244	0,547	0,000	0,547	0,066	0,194
11:00	2,311	1,145	1,166	0,000	1,166	0,067	0,195
12:00	2,925	1,332	1,593	0,000	1,593	0,059	0,183
13:00	2,252	0,507	1,745	0,000	1,745	0,058	0,181
14:00	2,615	0,677	1,938	0,000	1,938	0,054	0,175
15:00	3,366	1,543	1,823	0,000	1,823	0,055	0,176
16:00	2,357	1,067	1,290	0,000	1,290	0,060	0,185
17:00	2,198	1,513	0,685	0,000	0,685	0,065	0,192
18:00	1,698	1,509	0,189	0,000	0,189	0,069	0,199
19:00	2,292	2,279	0,013	0,000	0,013	0,079	0,214
20:00	2,696	2,696	0,000	0,000	0,000	0,077	0,211
21:00	2,822	2,822	0,000	0,000	0,000	0,061	0,186
22:00	1,584	1,584	0,000	0,000	0,000	0,055	0,176
23:00	1,434	1,434	0,000	0,000	0,000	0,056	0,177
0:00	1,335	1,335	0,000	0,000	0,000	0,054	0,175

Grid Defection Energy Balance – Guadalajara (May week)

Hour	Demand	Self Consumption	Non Used	PV Generation	Battery Storage Discharge	Battery Storage Charge
1:00	0,246	0,000	0,000	0,000	0,246	0,000
2:00	0,231	0,000	0,000	0,000	0,231	0,000

3:00	0,229	0,000	0,000	0,000	0,229	0,000
4:00	0,215	0,000	0,000	0,000	0,215	0,000
5:00	0,239	0,000	0,000	0,000	0,239	0,000
6:00	0,229	0,005	0,000	0,005	0,224	0,000
7:00	0,406	0,406	0,765	1,171	0,000	0,000
8:00	0,508	0,508	3,816	4,323	0,000	0,000
9:00	0,689	0,689	7,303	7,991	0,000	0,000
10:00	0,510	0,510	11,127	11,637	0,000	0,000
11:00	0,652	0,660	14,228	14,888	0,000	0,008
12:00	0,784	0,784	16,143	16,927	0,000	0,000
13:00	0,715	4,047	13,689	17,736	0,000	3,332
14:00	0,802	0,802	16,308	17,110	0,000	0,000
15:00	0,493	0,493	15,449	15,943	0,000	0,000
16:00	0,566	0,566	13,856	14,423	0,000	0,000
17:00	0,522	0,522	11,321	11,843	0,000	0,000
18:00	0,378	0,378	8,350	8,728	0,000	0,000
19:00	0,349	0,349	5,068	5,417	0,000	0,000
20:00	0,398	0,398	1,491	1,889	0,000	0,000
21:00	0,639	0,177	0,000	0,177	0,462	0,000
22:00	0,448	0,000	0,000	0,000	0,448	0,000
23:00	0,445	0,000	0,000	0,000	0,445	0,000
0:00	0,312	0,000	0,000	0,000	0,312	0,000

Grid Defection Energy Balance – Guadalajara (December peak)

Hour	Demand	Self Consumption	Non Used	PV Generation	Battery Storage Discharge	Battery Storage Charge
1:00	0,929	0,000	0,000	0,000	0,929	0,000
2:00	1,224	0,000	0,000	0,000	1,224	0,000
3:00	1,021	0,000	0,000	0,000	1,021	0,000
4:00	0,885	0,000	0,000	0,000	0,885	0,000
5:00	0,352	0,000	0,000	0,000	0,352	0,000

6:00	0,456	0,000	0,000	0,000	0,456	0,000
7:00	0,303	0,000	0,000	0,000	0,303	0,000
8:00	0,912	0,000	0,000	0,000	0,912	0,000
9:00	2,366	0,455	0,000	0,455	1,911	0,000
10:00	2,791	2,196	0,000	2,196	0,595	0,000
11:00	2,311	4,685	0,000	4,685	0,000	2,374
12:00	2,925	6,397	0,000	6,397	0,000	3,472
13:00	2,252	7,007	0,000	7,007	0,000	4,755
14:00	2,615	7,784	0,000	7,784	0,000	5,169
15:00	3,366	7,322	0,000	7,322	0,000	3,956
16:00	2,357	5,180	0,000	5,180	0,000	2,823
17:00	2,198	2,750	0,000	2,750	0,000	0,552
18:00	1,698	0,759	0,000	0,759	0,939	0,000
19:00	2,292	0,052	0,000	0,052	2,240	0,000
20:00	2,696	0,000	0,000	0,000	2,696	0,000
21:00	2,822	0,000	0,000	0,000	2,822	0,000
22:00	1,584	0,000	0,000	0,000	1,584	0,000
23:00	1,434	0,000	0,000	0,000	1,434	0,000
0:00	1,335	0,000	0,000	0,000	1,335	0,000

Grid Supply Energy Balance – Oviedo (May week)

Hour	Demand	Electricity Purchase	Wholesale price	Retail price
1:00	0,080	0,080	0,024	0,128
2:00	0,051	0,051	0,021	0,123
3:00	0,054	0,054	0,019	0,119
4:00	0,049	0,049	0,016	0,115
5:00	0,055	0,055	0,016	0,115
6:00	0,040	0,040	0,019	0,119
7:00	0,051	0,051	0,023	0,126

8:00	0,088	0,088	0,031	0,139
9:00	0,102	0,102	0,034	0,143
10:00	0,139	0,139	0,033	0,141
11:00	0,102	0,102	0,032	0,140
12:00	0,177	0,177	0,032	0,140
13:00	0,110	0,110	0,031	0,138
14:00	0,082	0,082	0,028	0,134
15:00	0,230	0,230	0,026	0,130
16:00	0,176	0,176	0,024	0,128
17:00	0,048	0,048	0,024	0,127
18:00	0,047	0,047	0,026	0,130
19:00	0,091	0,091	0,029	0,136
20:00	0,156	0,156	0,033	0,142
21:00	0,219	0,219	0,032	0,141
22:00	0,376	0,376	0,032	0,140
23:00	0,299	0,299	0,034	0,144
0:00	0,103	0,103	0,030	0,138

Grid Integrated Energy Balance – Oviedo (May week)

Hour	Demand	Electricity Purchase	Self Consumption	Export	PV Generation
1:00	0,080	0,080	0,000	0,000	0,000
2:00	0,051	0,051	0,000	0,000	0,000
3:00	0,054	0,054	0,000	0,000	0,000
4:00	0,049	0,049	0,000	0,000	0,000
5:00	0,055	0,055	0,000	0,000	0,000
6:00	0,040	0,039	0,001	0,000	0,001
7:00	0,051	0,033	0,017	0,000	0,017
8:00	0,088	0,046	0,065	0,000	0,065
9:00	0,102	0,000	0,081	0,045	0,126
10:00	0,139	0,000	0,139	0,043	0,182
11:00	0,102	0,000	0,102	0,126	0,228

12:00	0,177	0,000	0,177	0,097	0,274
13:00	0,110	0,000	0,110	0,194	0,304
14:00	0,082	0,000	0,082	0,212	0,294
15:00	0,230	0,000	0,230	0,056	0,287
16:00	0,176	0,000	0,176	0,092	0,269
17:00	0,048	0,000	0,048	0,173	0,221
18:00	0,047	0,000	0,047	0,117	0,164
19:00	0,091	0,000	0,057	0,046	0,103
20:00	0,156	0,114	0,042	0,000	0,042
21:00	0,219	0,211	0,007	0,000	0,007
22:00	0,376	0,376	0,000	0,000	0,000
23:00	0,299	0,299	0,000	0,000	0,000
0:00	0,103	0,103	0,000	0,000	0,000

Grid Integrated Energy Balance – Oviedo (December peak)

Hour	Demand	Electricity Purchase	Self Consumption	Export	PV Generation	Wholesale price	Retail price
1:00	0,630	0,630	0,000	0,000	0,000	0,048	0,165
2:00	0,550	0,550	0,000	0,000	0,000	0,047	0,164
3:00	0,584	0,584	0,000	0,000	0,000	0,044	0,159
4:00	0,098	0,098	0,000	0,000	0,000	0,038	0,150
5:00	0,110	0,110	0,000	0,000	0,000	0,035	0,146
6:00	0,076	0,076	0,000	0,000	0,000	0,038	0,149
7:00	0,074	0,074	0,000	0,000	0,000	0,048	0,165
8:00	0,075	0,075	0,000	0,000	0,000	0,063	0,189
9:00	0,185	0,182	0,003	0,000	0,003	0,066	0,193
10:00	0,159	0,130	0,029	0,000	0,029	0,066	0,194
11:00	0,821	0,748	0,073	0,000	0,073	0,067	0,195
12:00	0,619	0,503	0,116	0,000	0,116	0,059	0,183
13:00	1,384	1,235	0,149	0,000	0,149	0,058	0,181
14:00	1,660	1,506	0,154	0,000	0,154	0,054	0,175

15:00	2,148	2,016	0,132	0,000	0,132	0,055	0,176
16:00	0,853	0,761	0,092	0,000	0,092	0,060	0,185
17:00	0,879	0,828	0,051	0,000	0,051	0,065	0,192
18:00	0,482	0,467	0,015	0,000	0,015	0,069	0,199
19:00	0,451	0,450	0,001	0,000	0,001	0,079	0,214
20:00	1,846	1,846	0,000	0,000	0,000	0,077	0,211
21:00	1,582	1,582	0,000	0,000	0,000	0,061	0,186
22:00	1,313	1,313	0,000	0,000	0,000	0,055	0,176
23:00	1,413	1,413	0,000	0,000	0,000	0,056	0,177
0:00	0,694	0,694	0,000	0,000	0,000	0,054	0,175

Grid Defection Energy Balance – Oviedo (May week)

Hour	Demand	Self Consumption	Non Used	PV Generation	Battery Storage Discharge	Battery Storage Charge
1:00	0,080	0,000	0,000	0,000	0,080	0,000
2:00	0,051	0,000	0,000	0,000	0,051	0,000
3:00	0,054	0,000	0,000	0,000	0,054	0,000
4:00	0,049	0,000	0,000	0,000	0,049	0,000
5:00	0,055	0,000	0,000	0,000	0,055	0,000
6:00	0,040	0,016	0,363	0,379	0,024	0,000
7:00	0,051	0,051	1,440	1,491	0,000	0,000
8:00	0,088	0,111	2,913	3,024	0,000	0,000
9:00	0,102	0,081	4,167	4,248	0,000	0,000
10:00	0,139	0,145	5,305	5,451	0,000	0,007
11:00	0,102	0,102	6,330	6,431	0,000	0,000
12:00	0,177	0,177	7,104	7,281	0,000	0,000
13:00	0,110	0,117	6,891	7,008	0,000	0,007
14:00	0,082	0,082	6,573	6,655	0,000	0,000
15:00	0,230	0,230	4,966	5,196	0,000	0,000
16:00	0,176	1,414	5,204	6,618	0,000	1,238
17:00	0,048	0,048	3,837	3,885	0,000	0,000

18:00	0,047	0,047	2,394	2,441	0,000	0,000
19:00	0,091	0,057	0,838	0,896	0,000	0,000
20:00	0,156	0,156	0,000	0,156	0,000	0,000
21:00	0,219	0,177	0,000	0,177	0,042	0,000
22:00	0,376	0,007	0,000	0,007	0,370	0,000
23:00	0,299	0,000	0,000	0,000	0,299	0,000
0:00	0,103	0,000	0,000	0,000	0,103	0,000

Grid Defection Energy Balance – Oviedo (December peak)

Hour	Demand	Self Consumption	Non Used	PV Generation	Battery Storage Discharge	Battery Storage Charge
1:00	0,630	0,000	0,000	0,000	0,630	0,000
2:00	0,550	0,000	0,000	0,000	0,550	0,000
3:00	0,584	0,000	0,000	0,000	0,584	0,000
4:00	0,098	0,000	0,000	0,000	0,098	0,000
5:00	0,110	0,000	0,000	0,000	0,110	0,000
6:00	0,076	0,000	0,000	0,000	0,076	0,000
7:00	0,074	0,000	0,000	0,000	0,074	0,000
8:00	0,075	0,000	0,000	0,000	0,075	0,000
9:00	0,185	0,083	0,000	0,083	0,102	0,000
10:00	0,159	0,691	0,000	0,691	0,000	0,532
11:00	0,821	1,730	0,000	1,730	0,000	0,909
12:00	0,619	2,759	0,000	2,759	0,000	2,140
13:00	1,384	3,527	0,000	3,527	0,000	2,143
14:00	1,660	3,656	0,000	3,656	0,000	1,996
15:00	2,148	3,131	0,000	3,131	0,000	0,983
16:00	0,853	2,191	0,000	2,191	0,000	1,338
17:00	0,879	1,199	0,000	1,199	0,000	0,320
18:00	0,482	0,354	0,000	0,354	0,128	0,000
19:00	0,451	0,030	0,000	0,030	0,421	0,000

20:00	1,846	0,000	0,000	0,000	1,846	0,000
21:00	1,582	0,000	0,000	0,000	1,582	0,000
22:00	1,313	0,000	0,000	0,000	1,313	0,000
23:00	1,413	0,000	0,000	0,000	1,413	0,000
0:00	0,694	0,000	0,000	0,000	0,694	0,000