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EVALUACIÓN DEL IMPACTO DE RECURSOS ENERGÉTICOS DISTRIBUIDOS EN EL SISTEMA ELÉCTRICO

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Fdo.: …………………… Fecha: 17/ 06/ 2015

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Content

1. Resumen

El objetivo de este proyecto es determinar los costes de incrementar redes producidos por un incremento en la demanda bajo distintas condiciones de implantación de programas de respuesta de la demanda. Dentro de estos costes se incluirán todos los equipos y materiales a utilizar como son cables, transformadores, subestaciones y equipos de protección; los costes de mantenimiento de las futuras redes cuantificados anualmente tanto preventivos como correctivos; y los gastos por obra civil entre los que se incluyen zanjas, fachadas y postes.

La respuesta de la demanda es definida como las medidas tomadas para trasladar los consumos en las horas cuando la energía es más cara a aquellas con la energía más barata. En éste contexto y para definir los futuros casos de estudio hay que destacar dos aspectos importantes de los programas de respuesta de la demanda que se han estudiado en este proyecto. El primero de ellos es la elasticidad, que es la capacidad que tienen los consumidores para adaptar su perfil de consumo a otro en el que los costes sean menores. El otro aspecto es la existencia o no de un coste de consumo pico con el cual se penaliza al consumidor por su consumo máximo de potencia anual ya que la potencia pico es un factor crítico para la planificación y diseño de las redes eléctricas. En el caso de España sí existe este coste y asciende a un valor de 3,5€/kW-año.

Para llevar a cabo el estudio de costes se utiliza el Modelo Red de Referencia que es una herramienta de planificación de redes eléctricas que utiliza coordenadas GPS y la potencia de cada cliente. El modelo diseña las redes de alta, media y baja tensión y planifica la distribución de las subestaciones de transformación así como sus características técnicas teniendo en cuenta las características geográficas de la zona donde se quiere implantar la red. El proceso de utilización del Modelo Red de Referencia puede ser dividido en dos etapas claramente diferenciadas. En la primera etapa se utiliza el llamado "Greenfield Model" con el cual se simulan las condiciones iniciales de las redes, se crean redes parecidas a las existentes. En un segundo paso se utiliza el "Brownfield Model" que diseña los incrementos en las redes iniciales necesarios para satisfacer un crecimiento de la demanda bajo distintos perfiles de consumo modificados por las distintas formas de implantación de respuesta de la demanda explicadas más adelante.

Para llevar a cabo este estudio se consideran dos zonas en las cuales la implantación de programas de respuesta de la demanda podría tener diferentes efectos en los costes totales de incremento de las redes. Los lugares elegidos son el centro de la ciudad de Madrid como zona representativa de red urbana y una zona Villalba de la Sierra y Zarzuela (Cuenca) como zona representativa de red rural.

En primer lugar se crean los perfiles de consumo modificados con respuesta de la demanda. Para ello se diseña un programa de optimización que minimiza los costes totales de facturación de energía eléctrica de los clientes para distintos grados de elasticidad suponiendo la existencia o no de un coste de pico de potencia que incrementara las facturas.

A continuación se crean las redes iniciales utilizando el Greenfield Model para seguidamente crear las redes incrementales con el Brownfield Model utilizando los perfiles de consumo creados previamente. Se llevarán a cabo diversos casos de estudio en función de los siguientes

parámetros para determinar su influencia en los costes de inversión totales de las redes incrementales:

- Elasticidad: tal y como se ha explicado anteriormente la elasticidad es la capacidad que tienen los usuarios de adaptar sus perfiles de consumo para ahorrar dinero en sus facturas eléctricas.
- Coste de potencia máxima: coste adicional que incrementa la factura eléctrica en forma proporcional al pico de consumo anual.
- Adopción de la respuesta de la demanda de los usuarios: define la cantidad de consumidores del área de estudio que deciden participar en el programa de respuesta de la demanda del caso de estudio.
- Distribución: cómo quedan distribuidos los clientes que deciden seguir el programa de respuesta de la demanda dentro de la zona de estudio.

Para los casos que se estudian se decide crear las redes incrementales bajo un crecimiento en el consumo constante del 2% durante 10 años manteniendo todos los parámetros constantes menos uno que será el parámetro de control de cada caso.

El primer caso de estudio es la determinación del impacto del coste de potencia máxima consumida. Se concluye que en España la existencia de este coste extra es algo positivo ya que produce dos consecuencias que hace que la implantación de la respuesta de la demanda sea beneficiosa:

- Las redes incrementales creadas con respuesta de la demanda y coste de capacidad son más pequeñas y baratas mientras que los costes se disparan si no existe este coste.
- Los costes de facturación eléctrica con respuesta de la demanda quedan significativamente reducidos cuando existe este coste adicional lo que incentivará en mayor medida a los clientes a implantar los programas de respuesta de la demanda.

El segundo caso de estudio es la determinación del impacto de la elasticidad en los costes totales de inversión de las redes incrementales. Para este caso y los que siguen a continuación se supone que existe el coste de potencia máxima ya que se corresponde con el caso de España. Se pudo determinar que el incremento de elasticidad es algo beneficioso porque reduce los costes de las redes incrementales pero llegado a un punto, los costes de redes no se reducirán más por mucho que se aumente la elasticidad.

El tercer caso de estudio es la determinación del impacto de la adopción de respuesta de la demanda por parte de los usuarios. Se concluye que con una adopción tan pequeña como es un 3% de la población, ya se produce una reducción importante de los costes y que llegado a una cierta adopción, 100% para el escenario rural y 35% para el urbano, los costes incrementales se eliminan casi del todo.

Para finalizar se lleva a cabo el estudio del impacto de la distribución de los clientes que adoptan sistemas de respuesta de la demanda en el área. Se han hecho dos casos de estudio. En el primero se distribuyen los clientes que adoptan programas de respuesta de la demanda de forma aleatoria por todo el mapa, y en el segundo la mitad de los clientes que adoptan programas de respuesta de la demanda son concentrados en una zona concreta del mapa mientras que el resto se distribuyen de forma aleatoria. El resultado es que los costes de inversión de las redes incrementales se mantienen constantes por lo que se puede concluir que una concentración de usuarios de respuesta de la demanda de menos del 50% no produce cambios significativos en los costes de las redes incrementales.

2. Executive summary

The objective of this project consists of determining the network incremental cost produced by an increment in the demand under different demand response programs implementations. The network costs consist of the investment in all the equipments and materials to be used, such as wires, transformers, substations and protection equipment; the costs produced by the maintenance of the future networks, quantified annually, both preventive and corrective; and the spending on civil work including trenches, wall mounts and poles.

Demand response is defined as the measures taken to move the consumption in hours when the energy is more expensive to those when the energy is cheaper. In this context and in order to define future study cases, two important demand response program aspects that have been studied in this project have to be remarked. The first of them is the elasticity, which is the consumers' capacity to adapt their consumption profile to another so that the costs were lower. The other aspect is the existence or not of a peak demand consumption with which the consumer yearly maximum consumption is penalized as the demand peak is a critical factor for the electrical networks planning and design. In Spain it does exist and reaches a value of 3,5€/kW-year.

So as to carry out the costs study the Reference Network Model is used, which is an electrical network planning tool that uses GPS coordinates and the clients' demanded power. The model designs the high voltage, medium voltage and low voltage networks and plans the distribution of the transforming substations and its technical features taking into account the area geographical characteristics. The Reference Network Model process of usage can be divided into two clearly differentiated steps. In the first step, the Greenfield Model is used to simulate the network initial conditions; networks similar to the current ones are created. In a second step, the Brownfield Model designs the increments on initial network required to satisfy a demand growth under different consumption profiles modified by the different demand response implementation ways explained next.

In order to carry out the study two areas, in which demand response programs implementation might produce different effects on total incremental network costs, are considered. The chosen places are the centre of Madrid city representing an urban network; and an area between Villalba de la Sierra and Zarzuela (Cuenca) representing a rural network.

Firstly demand response modifying consumption profiles are generated. To do this, an optimization program that minimizes the total consumers' electricity bill is designed for the different elasticity degrees assuming or not the existence of a peak demand cost that increments the bills.

Initial networks are created using the Greenfield model and then generating the incremental networks with the Brownfield model and the profiles previously created. Several study cases will be carried out based on the following parameters to determine their influence on incremental network total investment costs:

- Elasticity: as previously explained elasticity is the users' capability to adapt their consumption profiles to save money on their electricity bills.
- Peak demand cost: additional cost that increases the electricity bill proportionally to the annual peak demand.
- Users' with demand response adoption: it defines the consumers' quantity living in the area that agree to participate in the considered demand response program.
- Distribution: how demand response adopting users are distributed around the area.

A constant growth of 2% during 10 years is chosen to generate the incremental networks keeping all the parameters constant except the one to determine its impact on incremental networks costs.

The first study case is the determination of the peak demand cost impact on total incremental costs. It is concluded that in Spain the inclusion of that extra cost is positive as it produces two consequences that turns the peak demand cost into something positive:

- Incremental networks are smaller and cheaper while bigger networks are planned when peak demand cost is not considered.
- Consumers' electrical bills are significantly reduced when peak demand cost exists, encouraging the costumers to participate in demand response programs.

The second study case is the determination of the elasticity impact on total incremental cost. For this and the next study cases it is assumed that the peak demand cost exists corresponding to the Spanish case. It can be determined that the increment of the elasticity is positive since it reduces incremental network costs. However from a maximum value of this parameter the costs are not reduced anymore.

The third study case is the determination of the impact of demand response on network costs depending on the number of consumers under the demand response program. It is concluded that a small adoption like a 3% of the consumers already produces an important reduction on incremental network costs, and when reaching certain adoption level, 100% for rural scenario and 35% for urban scenario, the incremental network costs are almost negligible.

To conclude, a study of the impact of the distribution of consumers adopting demand response over the case study zone on incremental network costs is carried out in two cases. The first one randomly distributes the demand response adopting users around the area. The second one concentrates half of them in a specific place in the area while the rest of them are randomly distributed. It can be concluded that if the concentration of the clients under the demand response program is lower than a 50%, the incremental network cost is almost negligible.

3. Introduction

Nowadays, the amount of several technologies connected to distribution networks (distributed energy resources), such as demand response, electric vehicles, solar photovoltaic and storage batteries are increasing significantly. In a European context, one of the main drivers for this growth is the support of electricity generation from renewable energy sources (RES) and combined heat and power (CHP) plants. In addition, the distribution business is a regulated activity which is, at least, legally and functionally unbundled from the generation activity. These issues, together with the fact that distribution networks were not originally designed to accommodate generation, pose significant challenges on distribution network planning and operation. In addition the recent expansion of the solar and wind energy generation combined with the distributed generation has turned the traditional generation systems into an under usage. In this context, current networks need to be modified in order to be more efficient by adapting them to the new situation. In this project, the impacts of distributed resources, in particular demand response programs, on distribution networks will be evaluated, starting from an original distribution network which represents an approximation of the real current networks. Then, additional scenarios will be created to adapt the network to those new technologies using the Reference Network Model to establish the impact of new technologies on the incremental networks costs.

3.1.RNM model

According to Mateo et al (2011) [MATE11], the Reference Network Model (RNM) is a very large-scale planning tool, which plans the electrical distribution network using the GPS coordinates and demanded power of every single customer with different distributed energy resources (DERs). RNM designs the high, medium and low voltage networks, planning both substations and feeders. For planning the network, it considers technical constraints, such as voltage limits, capacity constraints and continuity of supply targets. It also considers geographical constraints such as the street map, the topography and forbidden ways through such as nature reserves or lakes. The objective of the RNM is not to design the real network, but rather to build a reference network, whose cost is indicative of the efficient cost required for building a network. Initially this type of models was designed to serve as a regulation tool for assessing the distribution network costs under incentive regulation.

The model will be executed in two steps. In the first step, being called from now on “Greenfield model”, the initial network resembling the existing one will be created. In the second step the incremental model, the “Brownfield model”, creates the incremental network as seen in Figure 1.

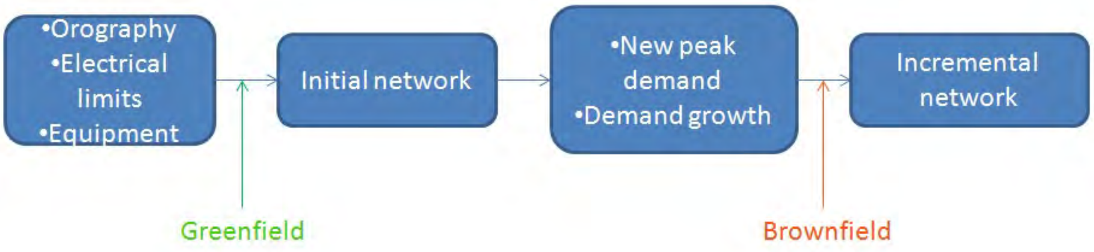

Figure 1: RNM diagram

3.2.Demand response

Demand response is defined as the changes in terms of electricity usage taken by the users to reduce their electricity cost. The process is simple and consists of reducing the consumption in those hours with higher prices and moving it to hours with lower prices as shown in Figure 2.

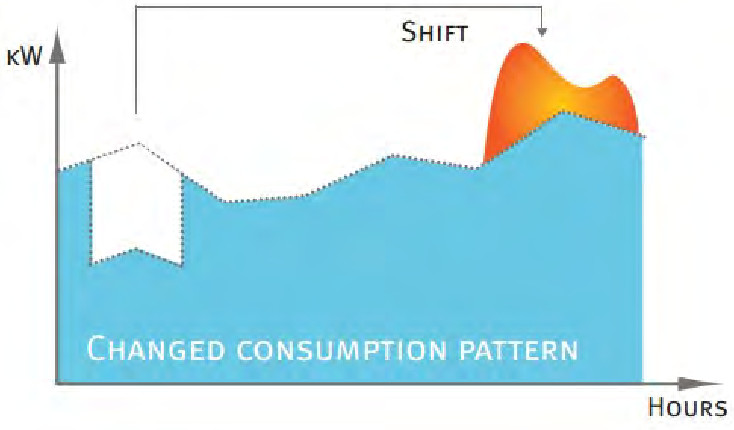

Figure 2: Demand response

During the last years, demand response has appeared in many different ways. According to the degree of interaction between consumers and the electrical system, the demand response can be classified in the following types.

Level 1 Efficiency and saving programs:

Implementation of efficient electrical equipment reducing the total demand but not taking into account the hourly consumption. These measures achieve energy savings and long term demand changes. The change in consumption can be seen in figure 3.

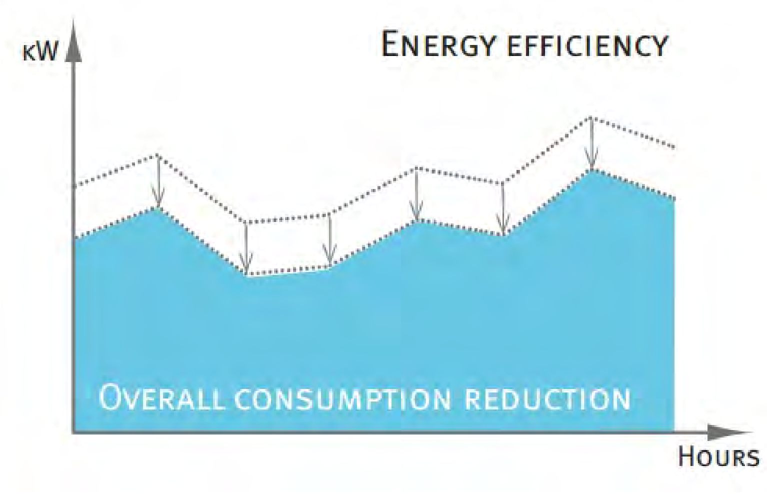

Figure 3: Efficiency programs

Level 2 Indirect electrical load control programs with tariffs

Signals are sent to the customers so they can decide if they want to accommodate their demand to produce an energy saving. The most extended initiatives are exposed below:

- Time of use tariff: this sort of tariffs consists of defining the price at each hour of the day for each period of the year. In Spain tariffs for residential consumers have been differentiated into two periods: peak and off-peak hours.
- Critical peak pricing: high prices are charged in the critical peak consumption hours so as to reduce it as much as possible.
- Real time pricing: the purchase of electricity works as any other market and now the clients take part of it. Retail electricity prices are set hourly, which correspond to a pass-through from wholesale prices. It is difficult for the client to take an exhaustive control of his economical spent. With automated systems and smart appliances demand response can be achieved at lower costs and with lower inconvenience for consumers.

Level 3 Indirect electrical load control programs with incentives

Clients are encouraged to reduce their consumption during several periods of time in exchange for savings on their electrical bill. The consumption reduction is taken by the consumer himself.

Level 4 Direct electrical load control programs

The system operators disconnect certain loads of their clients. This system requires the existence of a direct communication system between the operator and the consumer. Furthermore, demand response can provide system services such as reserve provision.

Level 5 Demand response market programs

This level comprises the initiatives or market structures that let the clients take part by offering load reductions.

According to García et al (2013) [GARC13], in the case of Spain, the most important experiences of demand response are the night tariff, consisting of 50% saving prices for the night and slightly higher prices for the day for customers with a contracted power less than 15 kW; and the interruptible contract, intended for the industries which get important savings if they reduce their consumption if requested.

4. State of art

The Reference Network Model (RNM) has been used to evaluate the impact of many technologies on networks costs and to determine the benefits and inconvenient that can be obtained from implanting those technologies on the network. The last contributions on this issue are related next.

With respect of the use of RNM model to evaluate the impact of DERs on the network costs, Cossent et al (2010) [COSS11] made a quantification of the impact of distributed generation on distribution network costs in three real distribution areas. The distributed generation consists of installing low power generators situated geographically near to the consumption of the energy produced by them. Different scenarios of demand and generation were analyzed for each region. Two possible situations are taken into account in each scenario: maximum net demand and maximum net generation. The computation of the distribution network costs was carried out by means of the reference network model (RNM), the same model that has been used in this project. The methodology followed was similar to the one in this project building an initial network with the "Greenfield model" and expanding it with the "Brownfield model". Results showed that network costs, mainly investments, tend to increase as DG penetration increases. However, considerable differences among regions were found. DG penetration reaches a maximum of 500% in Kop van Noord, 37% in Mannheim and 33% in Aranjuez. However, these values should not be directly compared for various reasons. The use of different simultaneity factors result in each kW of contracted power of load or installed DG capacity producing a different effect on power flows in each area. Additionally, the distribution of load and DG across voltage levels varies from one area to another. For instance, LV peak demand in the German case is 7.05MW, whereas maximum DG production at LV amounts to 23MW. These issues are not considered in the computation of global DG penetration levels, albeit they indeed have an impact on power flows and network capacity requirements. Moreover, the DG penetration level cannot explain by itself the differences observed. Other factors that proved to be at least as relevant as the DG penetration levels are: costs of lines/transformers, voltage level at which DG is connected, relative location of DG and loads, and temporal integration with demand (modeled by the simultaneity factors). The assumptions made regarding the contribution of DG and load to power flows in extreme conditions (simultaneity factors) were identified as being especially important. For some scenarios with very large DG penetration, the total increase in network costs caused by DG was lower the higher the level of demand was. On the other hand, in those scenarios with a low DG penetration level, costs tended to increase with demand. This points out to the fact that managing to balance generation and load at each time may probably have a significant positive impact on network costs. Additionally, using less conservative planning assumptions, as a result of an adequate integration of DG, could significantly reduce DG-driven costs. However, specific regulatory mechanisms that effectively allow and encourage DSOs to consider DG as a feasible alternative to network investments in an unbundled environment are deemed necessary. At the same time, DSOs should be willing to adopt an active role in the implementation of new (more active) network management strategies.

Moisés et al (2008) [MOIS08] contribute for the development of an appropriate economic regulation framework that removes the barriers to microgeneration (µG) and microgrid (µGrid) development. Microgeneration (µG) is defined as the generators supplying a local network known as microgrid (µGrid) that can operate autonomously by disconnecting from the traditional grid. To contribute to the development, the relevant costs and benefits resulting from the establishment of µG and µGrid are identified and a methodology for sharing those costs and benefits among the involved economic agents is presented. The authors discuss the problem of creating and financing incentives to µG and µGrids through: (i) the identification of the relevant costs and benefits for the various players; (ii) the design of a sharing scheme that distributes costs and benefits in a way that all the actors improve their gains regarding the original situation (no µG and no µGrids). It was concluded that the network consumers remain paying the losses that they were paying before. The difference in losses will finance the incentive mechanism designed to support µG and µGrid.

Méndez et al (2006) [MEND06] propose a method to assess the impact of distributed generation (DG) on distribution networks investment deferral in the long-term. Due to the randomness of the variables that have an impact on such matter (load demand patterns, DG hourly energy production, DG availability, etc.), a probabilistic approach using a Monte Carlo simulation is adopted. Several scenarios characterized by different DG penetration and concentration levels, and DG technology mixes, are analyzed. Results show that, once initial network reinforcements for DG connection have been accomplished, in the medium and long-term, DG can defer feeder and/or transformer reinforcements.

Vallés et al (2014) [VALL14] assess the inherent economic benefits of Active Demand (AD) on distribution business perimeter from a societal perspective, including the different stakeholders such as the Distribution System Operator (DSO), consumers and AD aggregators. Furthermore, the regulatory barriers for the implementation of active demand in the different contexts of the European scene, focusing on the countries where demand response demos took place (Spain, Italy, Germany and France), are identified and some recommendations are provided in order to facilitate the future development of active demand in electric power systems. In conclusion, the results of the economic analysis show that active demand could effectively help distribution network operators to reduce investment cost, allowing for a more efficient network planning strategies. These avoided investments have been observed especially at LV networks and MV/LV transformers and not only in the MV network. Notwithstanding, one of the main conclusions of this work is that this potential is very dependent on local characteristics of the networks and too low to provide a strong signal to many consumers, but not all. Various local and country-specific circumstances have been observed to influence the desirability and the effectiveness of integrating certain forms of AD into network planning strategies for DSOs and regulators. In particular, the following aspects have proved to be of great relevance:

- Network expansion drivers. AD has a great potential to defer network investments whenever they are driven by significant load increases and small or hardly any new DG penetration, and only Dynamic Pricing has some potential to help to reduce reinforcement needs to integrate massive amounts of new Solar PV.

- Network typology. In general, urban networks capacity utilization is higher so reinforcements due to load increases are deemed more necessary. Therefore, AD has a strong potential to defer investments in that kind of scenario. However, this is clearly conditioned by the expansion drivers.

- Current level of network constraint. AD is expected to have a more positive impact on investments in highly constrained networks. For example, in densely populated areas where small load increases would easily cause overloads in network assets. This aspect is related to the network typology and the network expansion criteria because grids that have been designed to have ample capacity to absorb load increases and new network users or that supply geographically scattered small loads are in general less constrained.

- Location of responsive consumers, especially for low participation rates in AD. In general, it is more beneficial from the perspective of network investments that the location of consumers participating in AD is concentrated and under control by the network planner. A dispersed location is favorable if required reinforcements are uniformly distributed across the network.

It has been discussed that part of the achievable net benefits at distribution network level could be transferred to final customer and part could be kept by DSOs, according to the design of the remuneration mechanisms and the distribution network tariffs in the specific country reality. Retailers and other intermediaries could share part of these savings with customers. This means that even when the potential economic benefits of AD may be significant from the perspective of society as a whole, and therefore from the regulator standpoint, they may be dispersed across the value chain and among involved stakeholders. This may reduce the incentives for participation but not the need for the efficiency improvement that AD could bring to electricity systems and society.

From the revision of the main regulatory aspects that should be reviewed in order to unlock the potential of AD, the most critical concerns that have arisen are:

- The main regulatory barriers to develop AD are related to the difficulties to equally access and operate in the electricity markets. Some of these impediments are only physical or technological, but others are regulatory. Other barriers are related to difficulties already encountered when putting in practice any form of AD.

- DSO regulation could be revised in order to incentivize DSO to make long-term efficient investments and reward innovation more than focus on short-term optimization.

- Regulation should ensure that end users receive cost-reflective tariffs to make the most efficient decisions as a whole (considering as well simplicity concerns).

- DSO could be entitled the choice to count on certain forms of AD to alleviate congestions, which remain to be defined and delimited but a direct commercial relationship with customers may not be advisable in order to boost competition and new business models.

- A competitive market without entry barriers should be ensured for retailers, aggregators and other commercial agents to provide smart AD services.

- Standardization in relation to Smart Metering functionalities and smart appliances is an open issue of discussion but under certain circumstances, it could be advisable not only at MS level but even at EU level.

- Consumer protection should be guaranteed beyond the security of the data to the rights of consumers to be informed and be provided the tools to understand the new smart tariffs and complex contracts to which they can be exposed.

It is hence possible to improve the current regulatory practices for the application of Active Demand in the European context and consequently contribute to the achievement of the EU targets of energy efficiency improvement and consumer engagement and protection.

5. Motivation

As Vallés et al (2014) demonstrated, the implementation of demand response can bring benefits and important savings on distribution networks. However it is crucial to determine under what circumstances it is worthy to extend the usage of demand response programs and quantify the total savings, or extra costs in some cases, for the following reasons:

- The planning of more economic efficient networks has a direct impact on the consumers' electrical bill reducing it significantly.
- The construction of efficient networks has an impact on:
    - Electricity prices: lowering them.
    - Environmental policies: bigger performance implies less pollution
    - European policies: satisfy the efficiency European policies.

6. Methodology

6.1. Running the Greenfield model

In this first step the initial network is created. At this moment it is important to make a distinction between the two initial scenarios studied in this project:

- Rural scenario: located in an area between Villalba de la Sierra and Zarzuela, both located in the province of Cuenca, characterized for their low density of population and consumption.

- Urban scenario: located in the center of Madrid and characterized for its high density of population and consumption.

The geographical location of both scenarios can be seen on figures 4 and 5:

Figure 4: Rural location

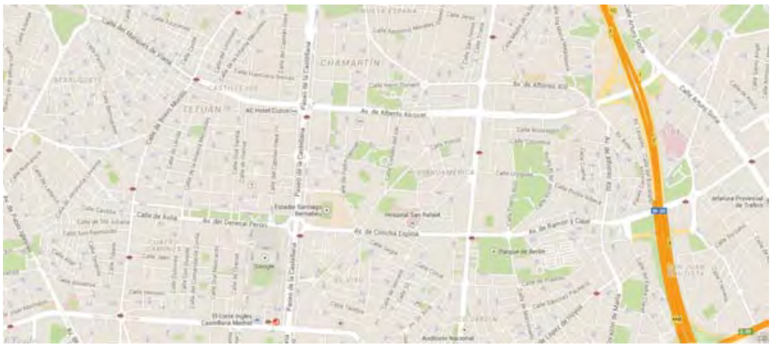

Figure 5: Urban location

The model will require the data contained in Figure 6 in which it is also explained the output data that the model returns. In addition, the layout of the network components can be shown topographically using ArcGis, which is a map processing program. All the data obtained in the simulation is collected in the annexes 1 and 2.

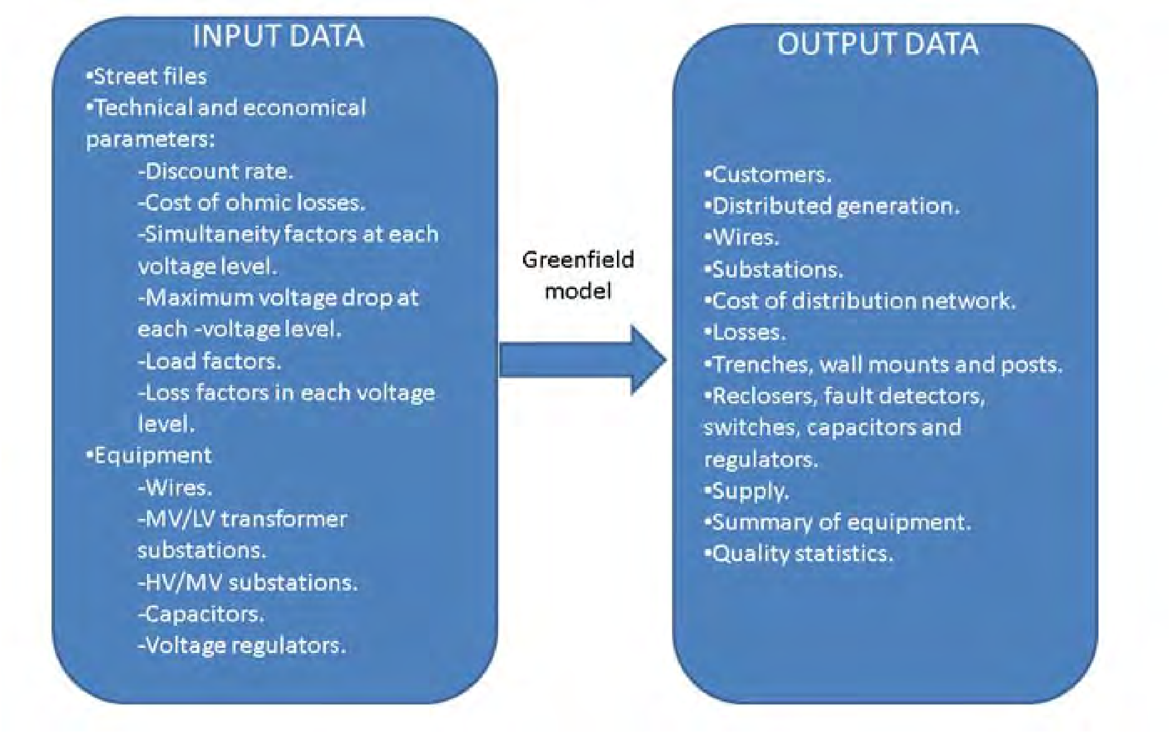

Figure 6: Greenfield data

The geographical layout of the network components can be seen in Figure 7 for the rural scenario and in Figure 8 for the urban scenario. For the sake of clarity, the different elements of the legend in those Figures are now explained:

- LvGrid: part of the network with a nominal voltage of 400V
- MvGrid: part of the network with a nominal voltage of 20kV
- HvGrid: part of the network with a nominal voltage of 66kV
- Mv/Lv: medium voltage to low voltage transformer substations indicating several data of each including nominal capacity, nominal voltage o losses among others.
- Hv/Mv: high voltage to medium voltage transformer substations indicating several data of each including nominal capacity, nominal voltage or losses among others.
- TransSub: transmission substations which serve as supply points into the distribution network.
- Clients: including Hv, Mv and Lv customers.
- NewNet: this will be the incremental network obtained with the Brownfield model

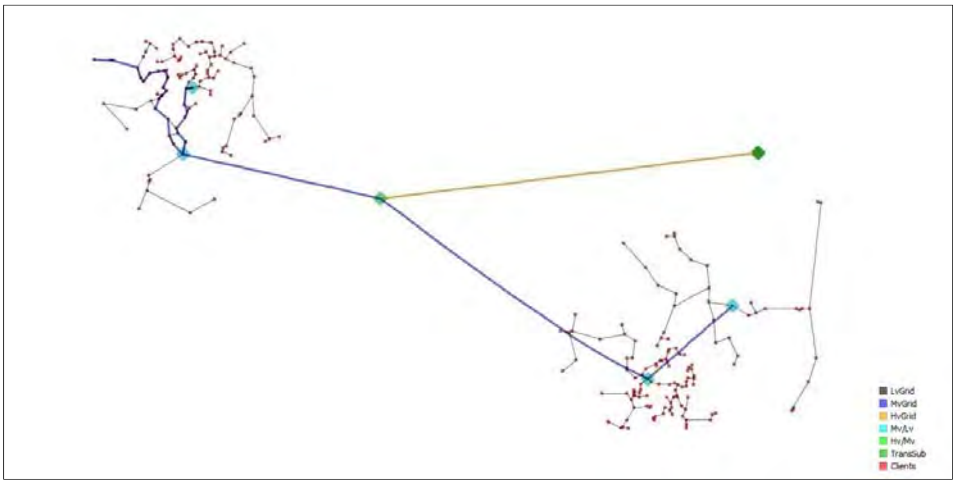

Figure 7: Rural initial network

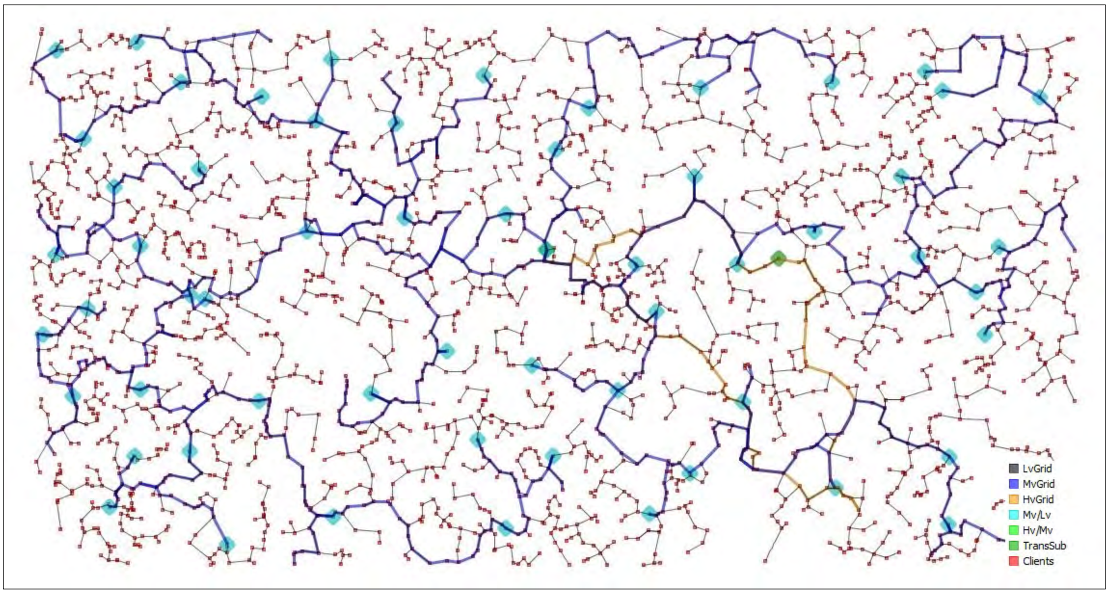

Figure 8: Urban initial network

6.2.Running the Brownfield model

6.2.1. Introduction

At this point, the initial network has already been built so, basing on this initial network, incremental networks that represent different scenarios are built. In order to build the incremental network, the following input data is required:

- Greenfield network.
- Lines catalog.
- HV/MV substations and MV/LV transformer substations catalog.
- Voltage regulators.
- Simultaneity factors.
- Clients demand profile.
- Demand growth.

In this project, the clients demand profiles and their distribution along the network are the study variables over which the network incremental are computed. Once the simulation is finished, the model returns the following output data:

- Number of customers and generators in the initial and incremental network.
- Contracted power for the clients depending on the adoption or not of the demand response program.
- Length of overhead and underground lines in the initial network.
- Power demand and losses in the networks of low (LV), medium (MV) and high voltage (HV) in the MV/LV transformer substations (TS) and the HV / MV substations (SS).
- For each voltage level and type of equipment: Summary of the investment costs, costs of preventive maintenance and corrective maintenance, Net Present Value (NPV) of investment and maintenance costs, NPV of losses costs, NPV of reliability equipment costs, total costs, and percentage of increase over the initial network costs.
- Estimated length and cost of trenches, wall mounts and poles.
- Reassignment (if applicable) of the voltage level of new clients and distributed generators.
- Electrical moment (kW x km) and distance (km) of new network from the electric power nodes.
- Quality indices (SAIDI and SAIFI), listed by town and reliability area.

  The SAIDI (System Average Interruption Duration Index) index is the average outage duration for each customer served and can be expressed as:

  $$SAIDI = \frac{sum\ of\ all\ customers\ interruption\ durations}{total\ number\ of\ customers\ served}$$

  The SAIFI (System Average Interruption Frequency Index) index is the average number of interruptions that a customer would experience and can be expressed as:

  $$SAIFI = \frac{total\ number\ of\ customer\ interruptions}{total\ number\ of\ customers\ served}$$

- List of equipment for the initial network for minimum reinforcement, and planned increases.

6.2.2. Case studies

6.2.2.1. Peak demand cost and elasticity

One of the main parts of the project consists of creating the customer’s new demand profile to execute the Brownfield model. Before doing it, it is important to mention that in Spain there is an extra cost on the peak demand (3,5€/kW-year), this is made by including a variable which measures the maximum energy consumption. For small consumers this charge comes from the contracted power, which is the maximum power available for the consumer.

The demand profile of customers that want to reduce their peak consumption by shifting demand and in that way reducing their bill payments will be determined by using an optimization model that satisfies the following constraints and targeting the following objective function. The model is run in GAMS and uses an Excel interface to import and export the models inputs and outputs.

- Objective function

$$\min f = \sum_{\in d,h} x(d,h) * c(d,h) + \ pdcond * pdcost * cmax$$

This function creates the new demand profile minimizing the final electricity bill. In this function it is considered both normal cost for energy and the extra cost for the complete year demand peak. X(d,h) is a variable representing the new consumption of the client in each hour (h) of each day (d). C is a parameter representing the cost of electricity in each hour of each day. Pdcond is a binary parameter that fills with a 1 if it is decided that the peak demand cost is included or 0 if not. Pdcost is the peak demand cost, in the case of Spain 3,5€/kW-year. Cmax is the highest consumption of the year.

- Constraints
  - Energy constraints

$$\sum_{h} x(d,h) = \sum_{h} y(d,h) \ \ \forall d$$

This constraint keeps the total energy of the new profile constant. The Y (d,h) is the initial customer load profile.

  - Limit constraint

$$lb * y(d,h) \leq x(d,h) \leq ub * y(d,h) \ \ \forall d,h$$

This constraint controls the maximum change in the hourly consumption of the new profile with respect the initial one. Lb and Ub are parameters that define the bounds in which the new profile consumption must be included. These parameters are related to the demand elasticity, which is the flexibility that the demand profile has to change.

  - Maximum consumption

$$cmax \ \geq \ x(d,h) \, \forall d,h$$

This constraint fills cmax with the maximum hourly consumption of the new demand profile for 1 year.

New demand profiles will be obtained with the previous formulation depending on the two parameters that can be modified. Those parameters are the pdcond that, as said before, it determines if the peak demand cost is considered or not; and the bounds, which will be called from now on demand elasticity, that defines the maximum hourly changes from the initial profile.

Figure 9 shows the new profiles for different levels of demand elasticity not considering the peak demand cost and Figure 10 shows the new profiles for different levels of demand elasticity considering the peak demand cost.

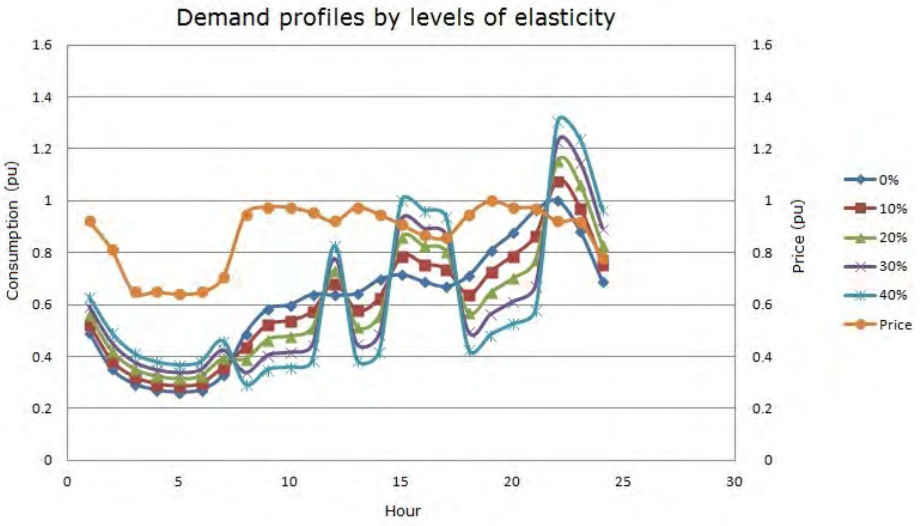

Figure 9: Demand profiles without peak demand cost

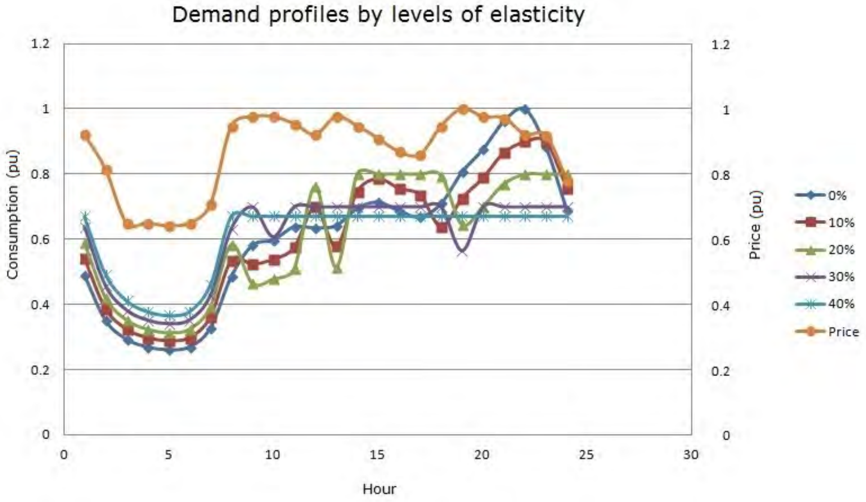

Figure 10: Demand profiles with peak demand cost

Peak demand increases significantly network costs. Networks are fundamentally designed to meet the peak demand.

The Greenfield model reinforces the initial network to meet the peak demand based on the new customer load profiles. For this reason, the day with the highest peak demand is selected. Therefore, the network would be able to meet that peak consumption. In case of distributed generation, peak generation would be an important variable to be also considered in the design the network.

As additional information, Table 1 shows the electricity cost, objective function value, as a result of the optimization model, that the customers would perceive each day if they follow the new demand profile (considering both the elasticity parameters and peak demand charge). The cost differential is based on the changes from the original cost according to the original demand profile.

Peak demand cost	Elasticity	Cost (New/original)
No	10.00%	99.30%
	20.00%	98.60%
	30.00%	97.89%
	40.00%	97.19%
Yes	10.00%	97.38%
	20.00%	95.28%
	30.00%	93.18%
	40.00%	92.55%

Table 1: User cost for different profiles

6.2.2.2. Adoption of demand response and distribution

The adoption of demand response refers to the number of consumers in the area that agree to modify their demand profile under the demand response program.

The customers with flexible demand are distributed in two ways:

- Concentrated: 50% of them are close between them and 50% are randomly distributed around the whole area.
- Dispersed: 100% of them are randomly distributed around the whole area.

In case of the concentrated scenario, the first step is calculating the number of clients with demand response with respect the total number of clients and the percentage of adoption. The next step consists of selecting a place in the area, being that point a parameter, and the program selects the closest clients to that point until the number of clients selected reaches half of the number of clients calculated previously as explained before. The selected point is chosen outside of the area, in the place shown in Figures 12 and 14, to concentrate the clients that adopt the demand response in the limits of the map. The rest of the clients with flexible demand are distributed randomly. The distribution differences can be seen in figures 11 to 14 representing the distribution of 35% clients that use demand response.

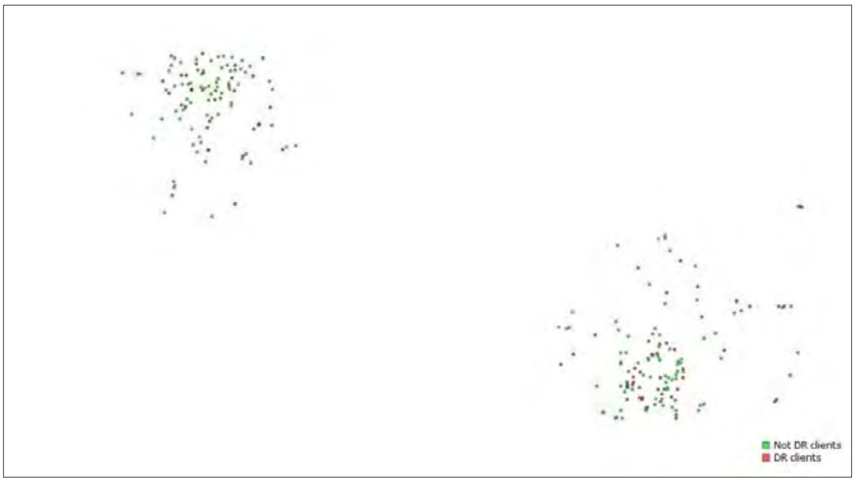

Figure 11: Rural dispersed distribution of customers with demand response (DR)

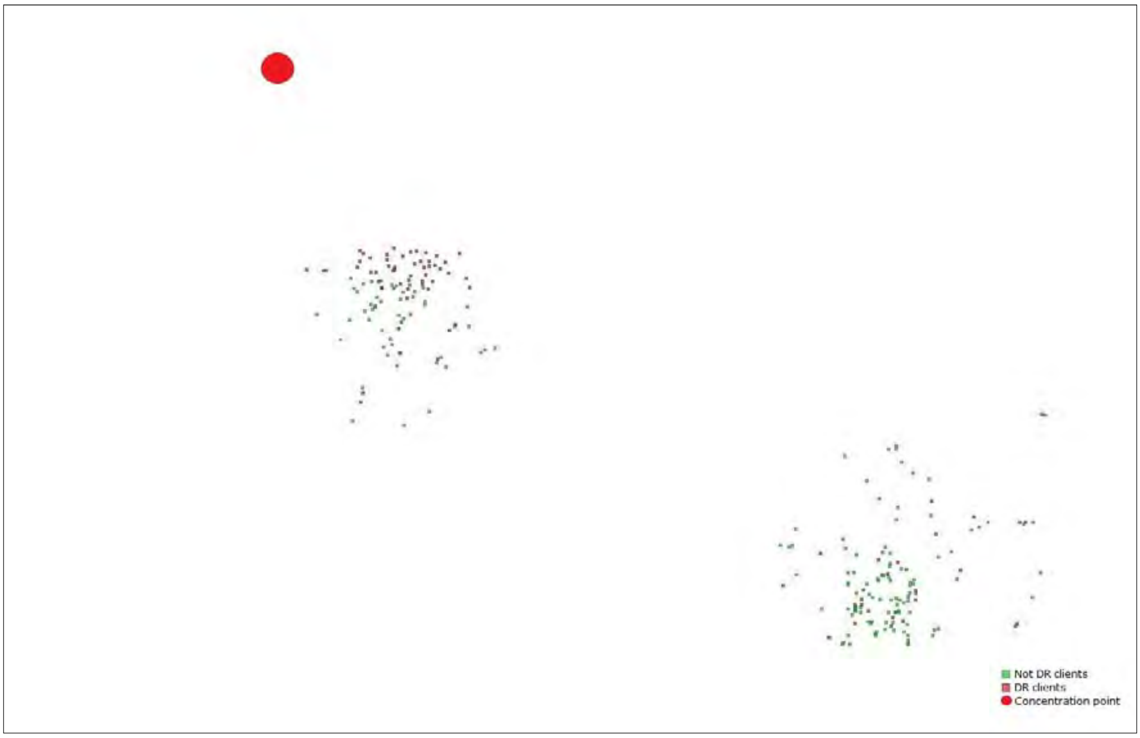

Figure 12: Rural concentrated distribution of customers with demand response (DR)

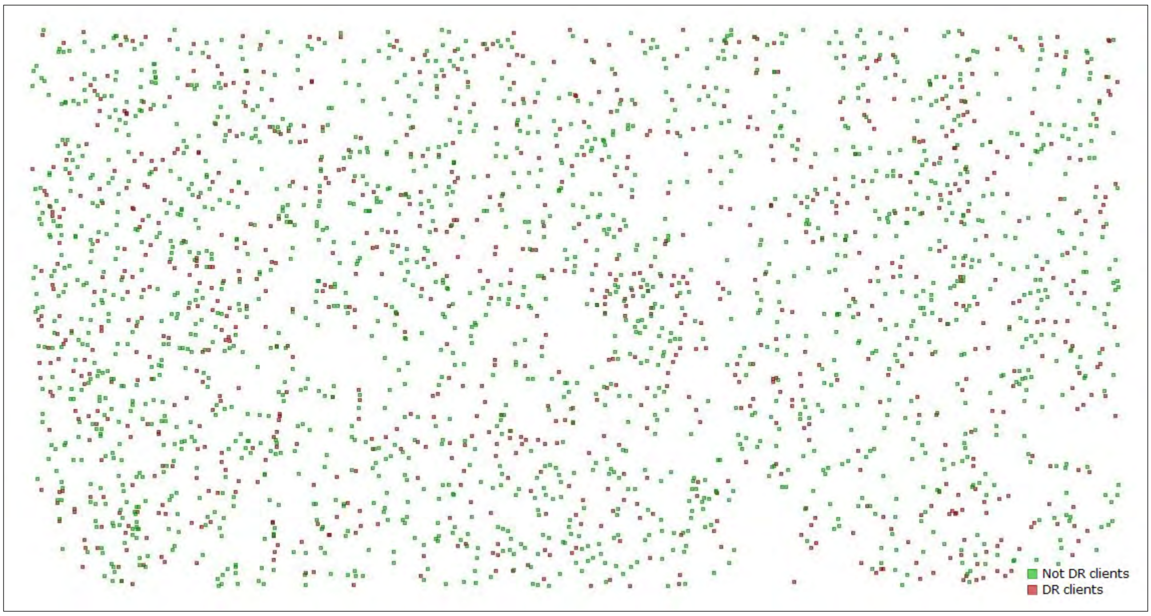

Figure 13: Urban dispersed distribution of customers with demand response (DR)

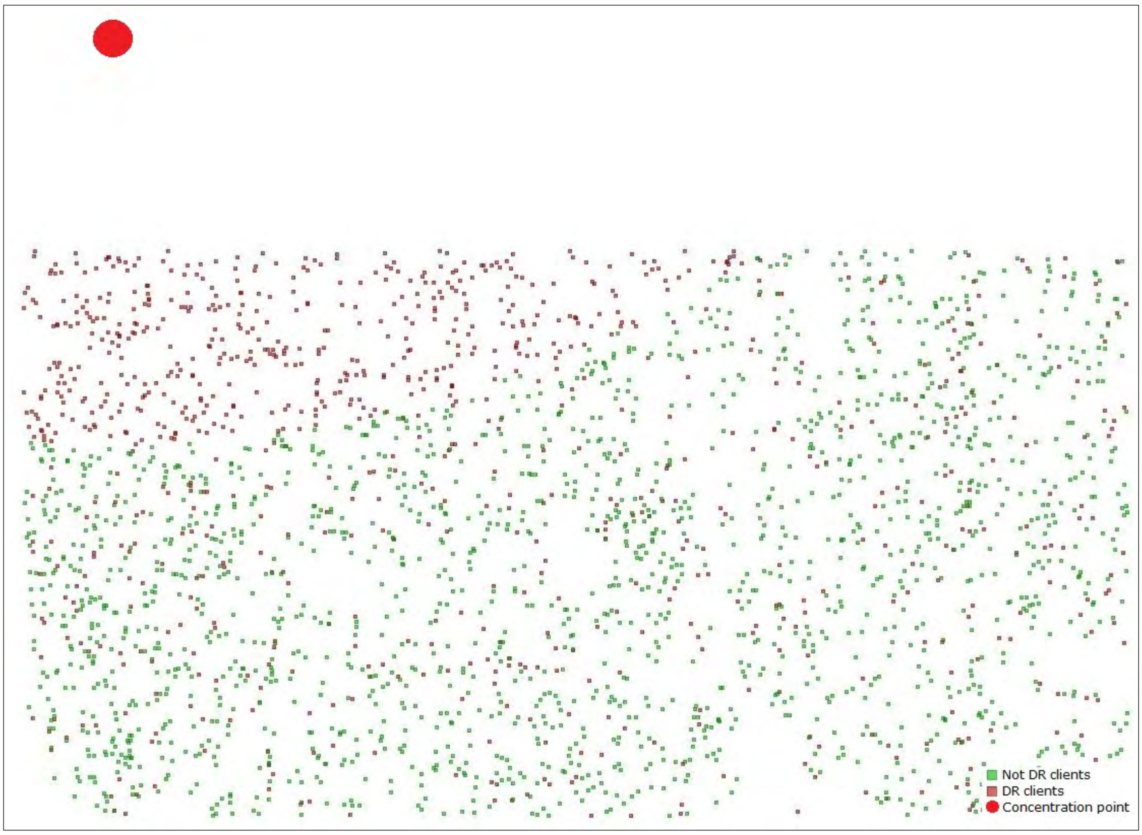

Figure 14: Urban concentrated distribution of customers with demand response (DR)

6.2.2.3. Summary of cases

As said before, the purpose of this project is to analyze the effects of the demand response program adoption on network incremental costs. Therefore it has been planned several scenarios to evaluate the impact in different possible situations. The assumed demand growth considered for the study will be a constant growth of 2% during 10 years. All different case studies are resumed in Figure 15.

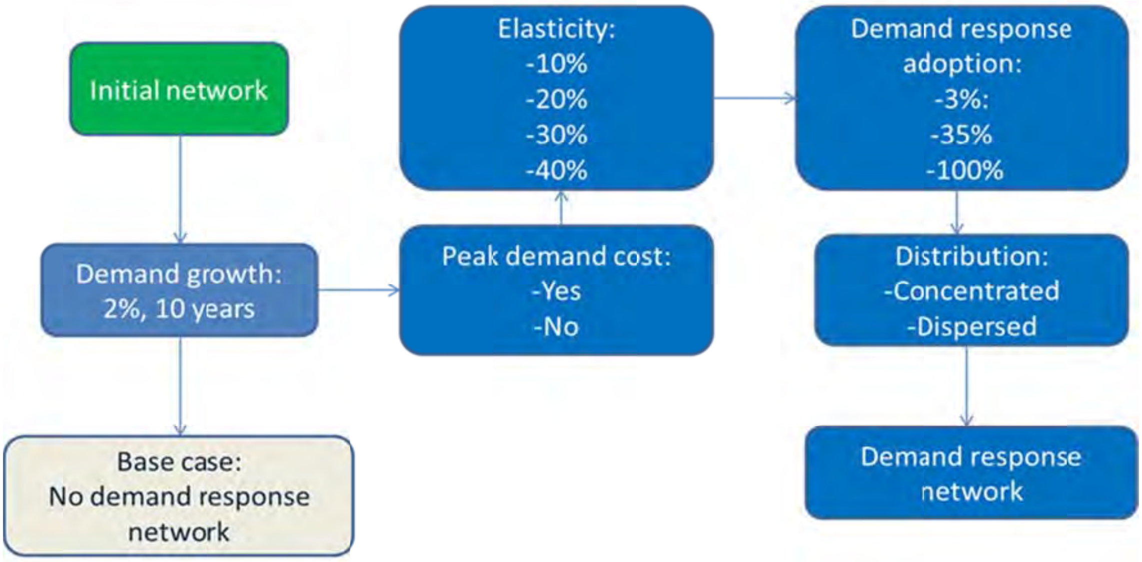

Figure 15: Cases of study

7. Case studies

In this part, it will be analyzed the effects of the different case studies on the incremental cost in both rural and urban scenarios reporting representative cases for all of the variables. The complete cost results are included in annex 3 and annex 4.

7.1.Peak demand cost

The peak demand cost is, as said before, a critical parameter since it significantly affects peak demand. In figures 16 and 17 the elasticity would be kept constant at 20% and a 100% of demand response adoption will be considered.

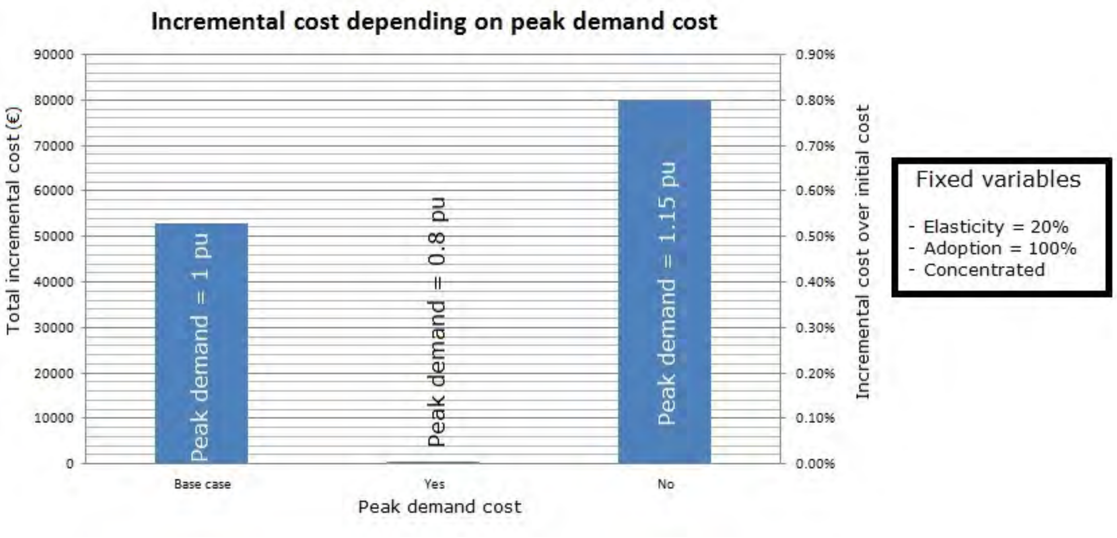

Figure 16: Rural peak demand cost study

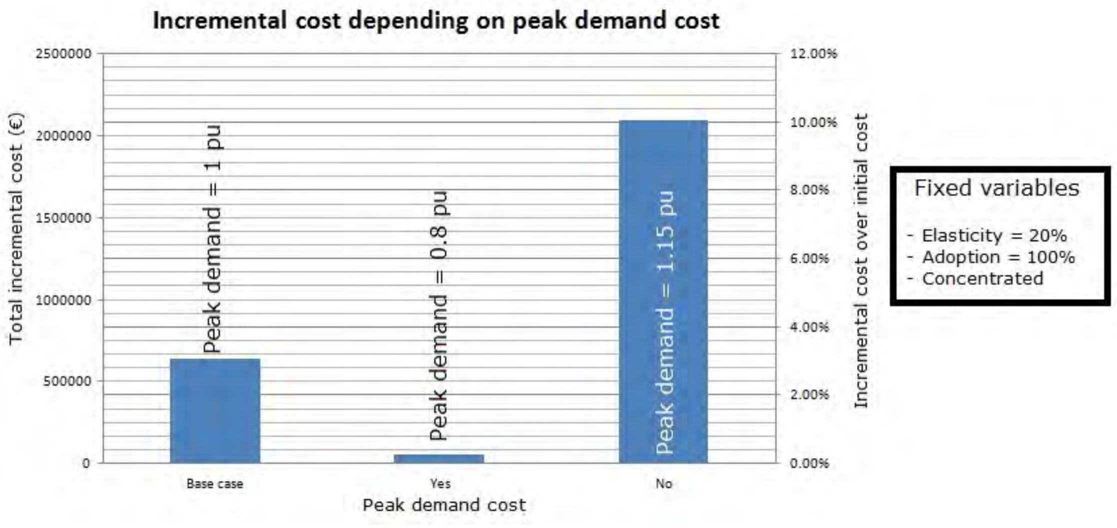

Figure 17: Urban peak demand cost study

According to Figures 16 and 17, the peak demand cost is a crucial factor that encourages the demand response in Spain, as without it, the costs of the incremental network rise dramatically. In addition, as seen on Table 1, the lack of peak demand cost does not affect much on the final electricity bill of the customers, so the consumers would not be very willing to change their original consumption profile to adapt it to the profile with demand response.

Furthermore, the incremental cost in urban network is higher compared to the initial network cost than the effect in rural network. Therefore, as shown in the presented case study, demand response has higher impact on urban networks in terms of network costs.

Network reinforcements can be represented graphically, meaning all the electrical equipment including lines, transformers, substations and protections. Figures 18 to 20 represent geographically the situation of the incremental lines. In Tables 2 and 3 it is collected a summary of the equipment needed. The incremental network for the rural scenario with peak demand cost is not represented since it is so small that it is difficult to be distinguished.

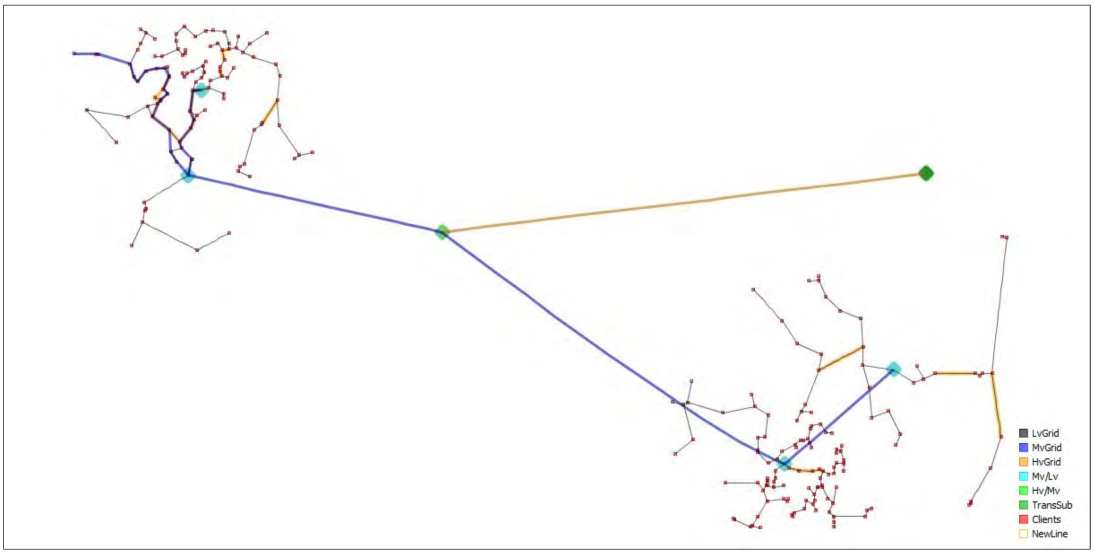

Figure 18: Rural incremental network without peak demand cost

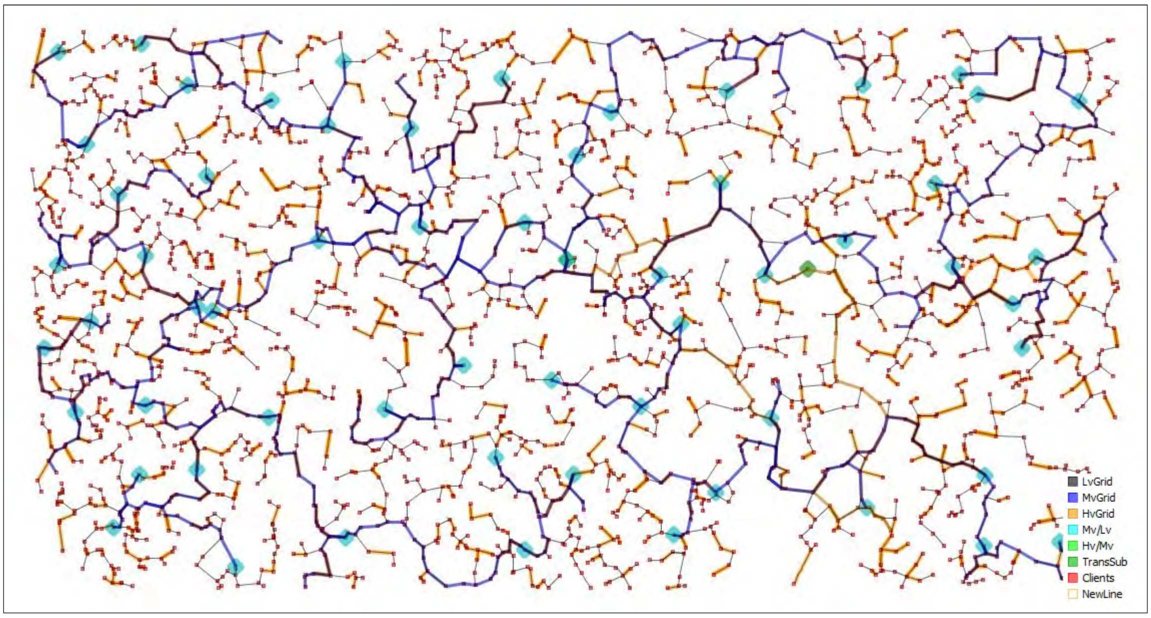

Figure 19: Urban incremental network without peak demand cost

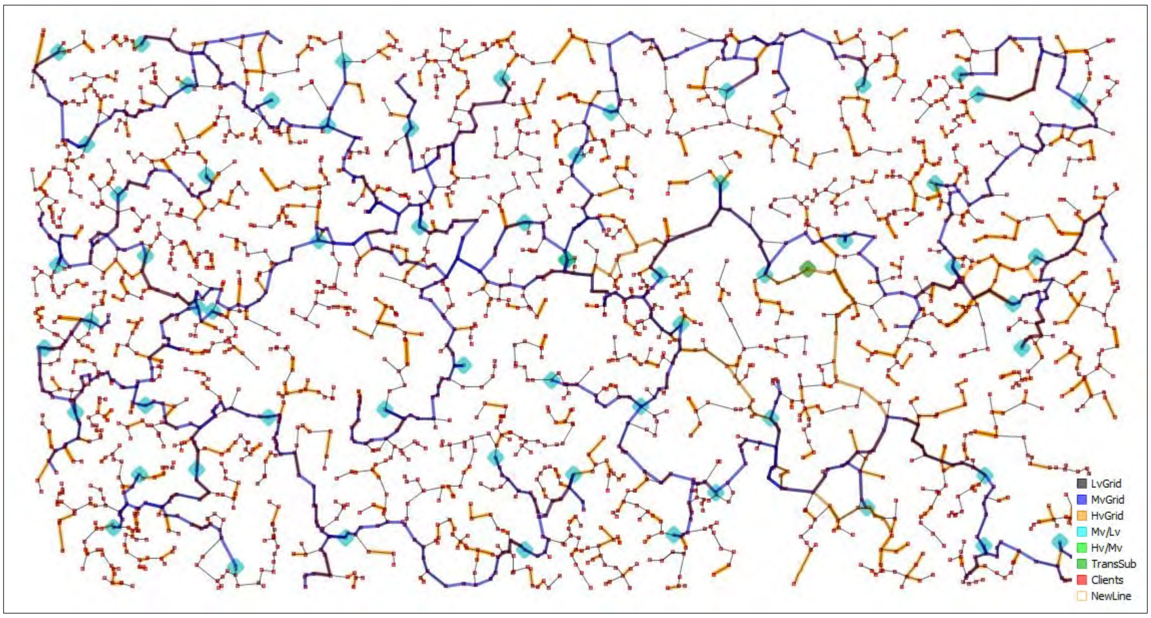

Figure 20: Urban incremental network with peak demand cost

Peak demand cost	Increment	Cost (€)
Yes	LV lines	318
No	LV lines	67736

Table 2: Detailed costs for rural network

Peak demand cost	Increment	Cost (€)
Yes	LV lines	39678
	Breaker	19600
No	LV lines	476342
	MV lines	392092
	Breaker	29400
	Switch	700

Table 3: Detailed costs for urban network

In conclusion, there are important extra increments on LV network costs when there is no peak demand cost. That does not happen in MV or HV networks because the current initial network is big enough. On the other hand, not having peak demand cost on urban networks has an extra impact on MV networks increasing the incremental cost.

7.2.Elasticity

The other way to change the consumers' demand profile is by modifying the elasticity, percentage of demand which can change from one to another. This is a critical variable since it can change peak demand as well as shown in Figures 7 and 8. For this case, it was decided to include the peak demand cost and an adoption of 100% of the clients to demand response programs. The results are shown in Figures 21 and 22.

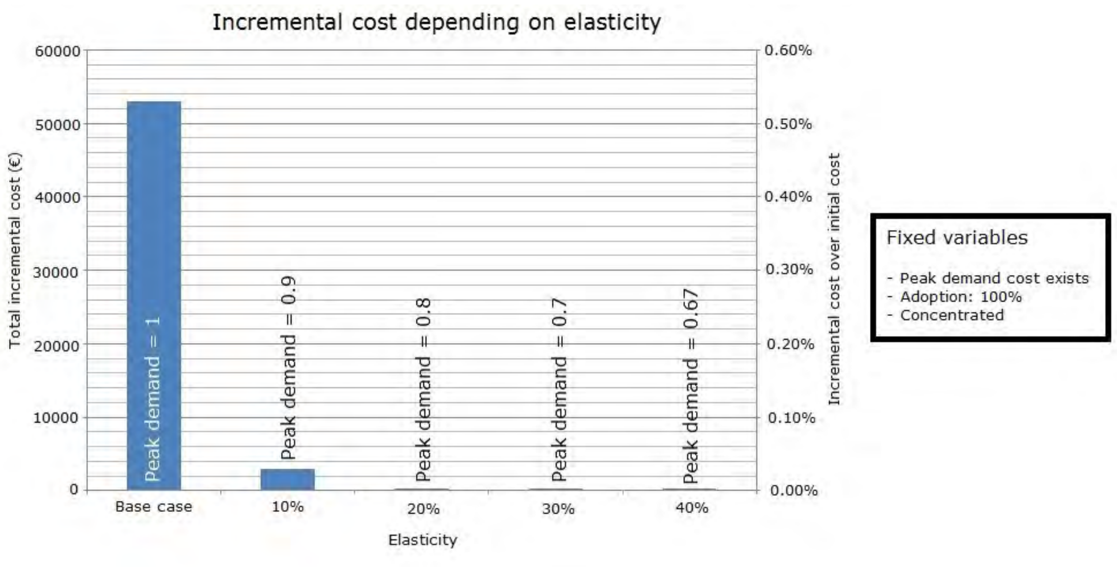

Figure 21: Rural elasticity study

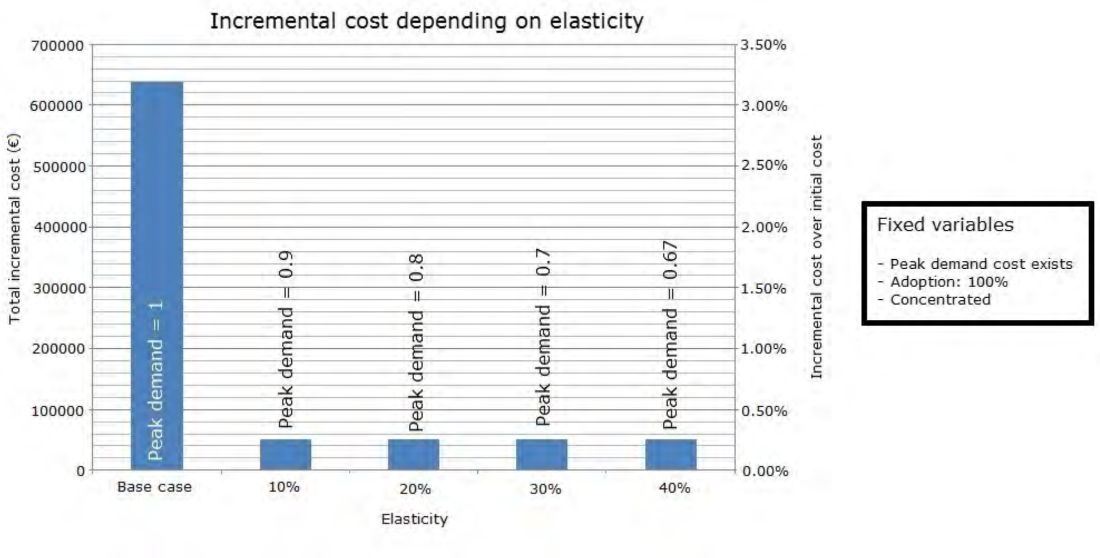

Figure 22: Urban elasticity study

As shown in Figures 21 and 22, the incremental network costs significantly are reduced with the elasticity parameter, but those costs reach a limit at a moment, 10% of elasticity for the urban network and 20% for the rural network, and do not reduce anymore. On the other hand, the minimum incremental cost almost reaches 0 when applying a 20% (or over) elasticity demand response program for the rural network and this is because rural networks are in an under usage state in comparison with the peak demand, so no increments would be needed to supply the incremental demand.

In Figure 23 it can be seen the increments on urban networks for the all the different cases of elasticity since the resulting networks are the same one as increasing the elasticity more than

10% do not produce a smaller network to accommodate the demand. The rural cases are not represented since the increments are too small to be represented.

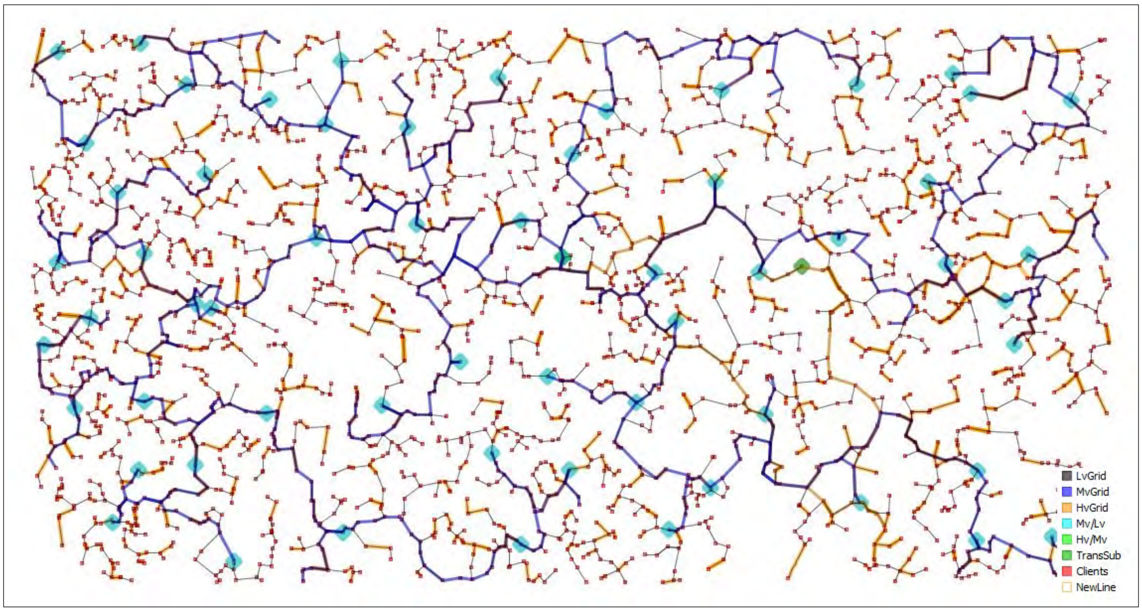

Figure 23: Urban incremental network with 10%-40% elasticity

As conclusion, the elasticity of the consumers does not have to be extremely high in terms of network costs since the incremental network cost will not be smaller.

7.3.Demand response adoption

The amount of people that agree to change their consumption profile would affect the final network costs. To measure the effect of demand response adoption, it is accounted for peak demand cost, 20% of demand elasticity and with a dispersed distribution of the clients. Relevant cases are chosen to see the impact of different adoption levels: 3% for an adoption of a minority of consumers, 35% for a feasible number of consumers to adapt their consumption, and 100% which is the optimum case. The results are shown in Figures 24 and 25.

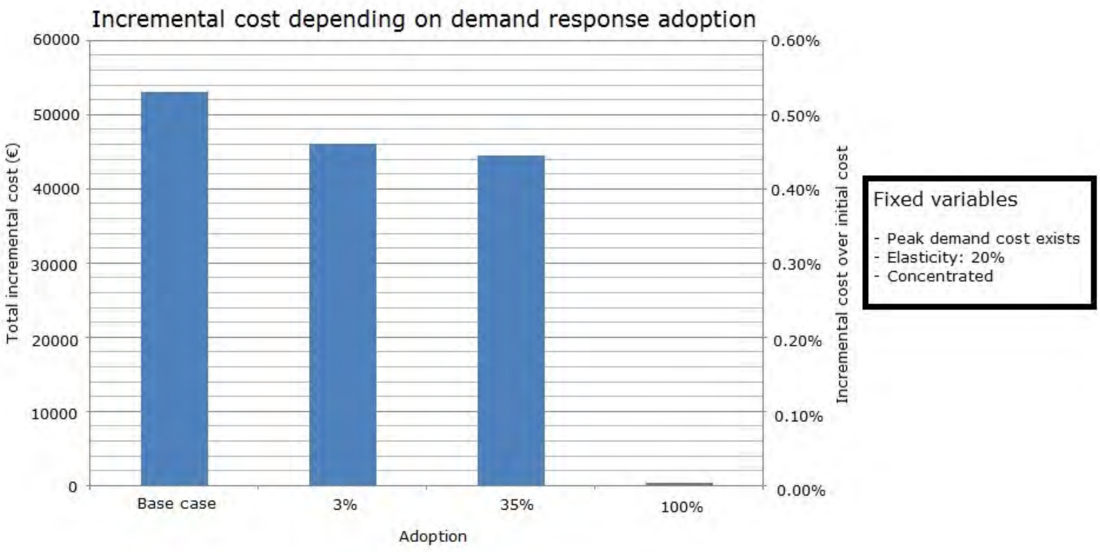

Figure 24: Rural adoption study

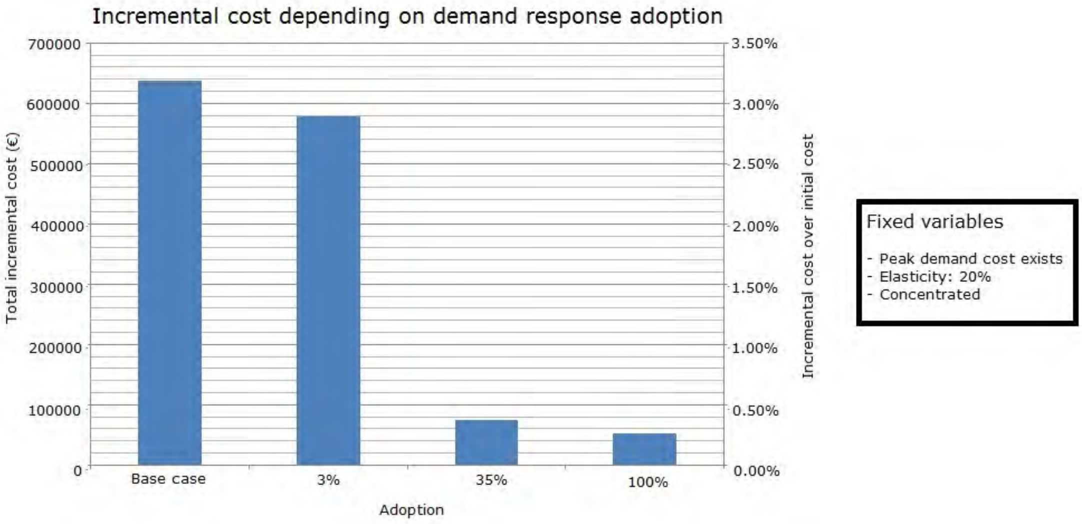

Figure 25: Urban adoption study

As shown in figures 25 and 26, there is an important reduction in the costs with just a 3% of adoption of the clients. However, the decrease that dramatically reduces network costs is different in the rural scenario in comparison with the urban one. With a 100% of adoption there´s a huge decrease on network costs in the rural scenario while in urban scenario, that big decrease is reached at a 35% of adoption.

The incremental networks for different demand response adoption are shown in Figures 27 to 30. For the rural scenario, only in the 3% adoption case the incremental network is appreciable because the incremental network is too small to be represented by the program.

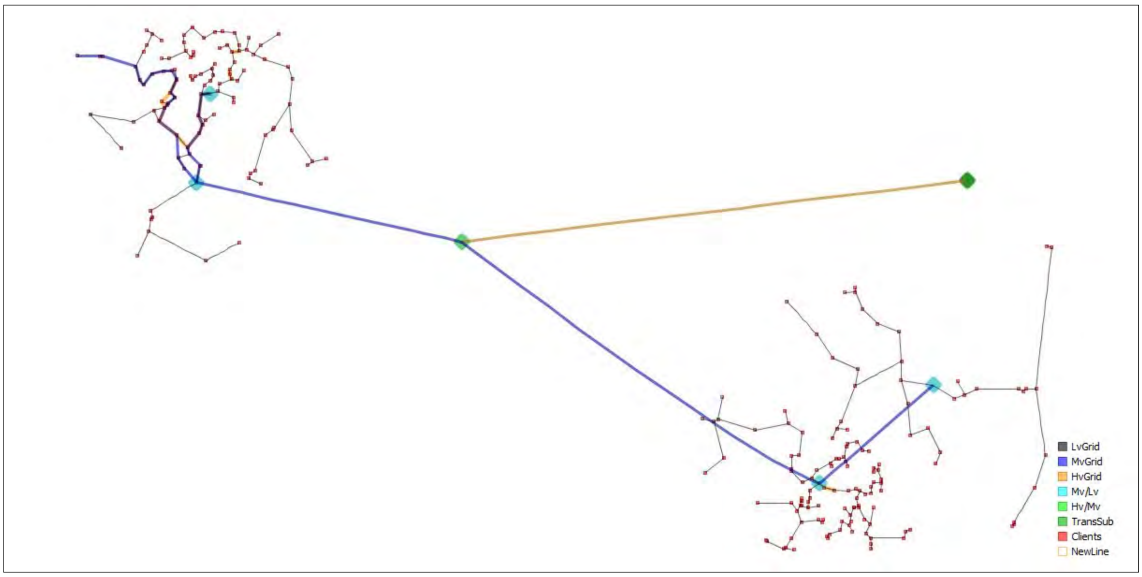

Figure 26: Rural incremental network for 3% adoption

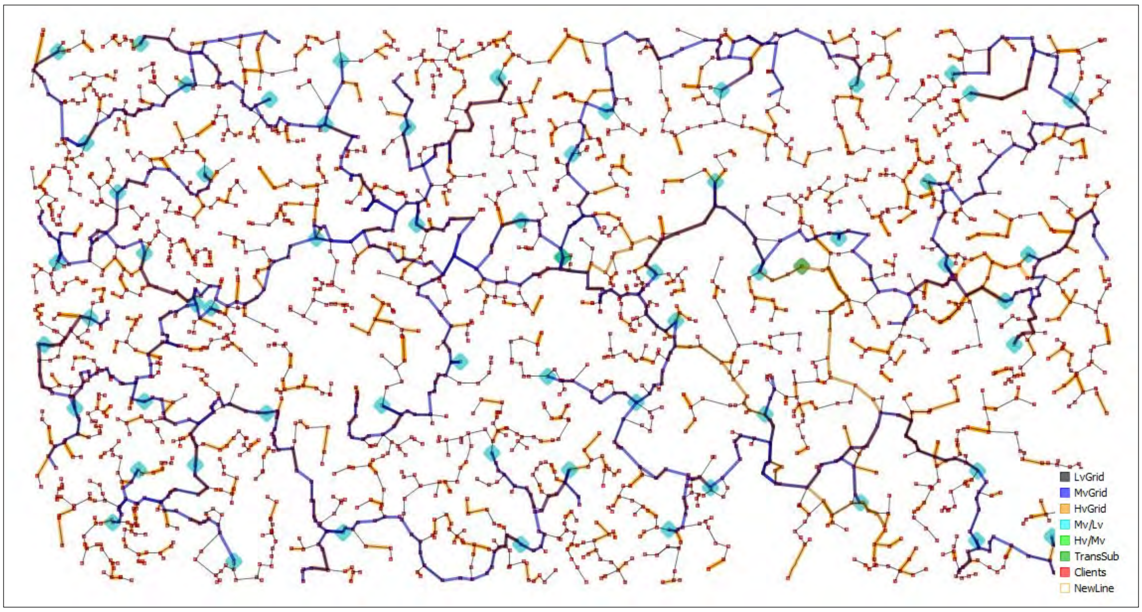

Figure 27: Urban incremental network for 3% adoption

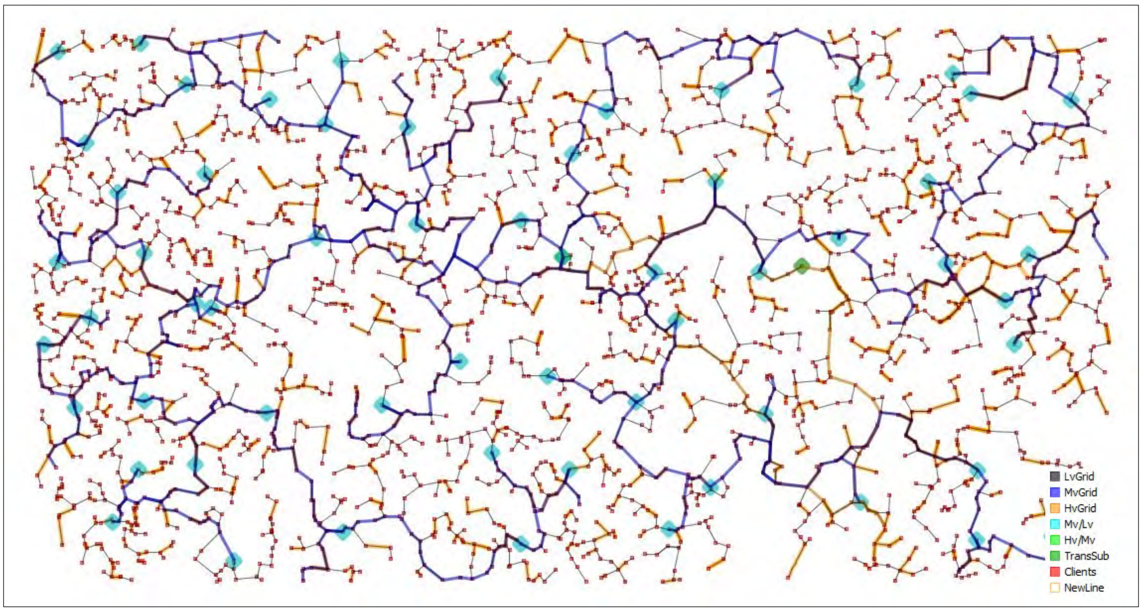

Figure 28: Urban incremental network for 35% adoption

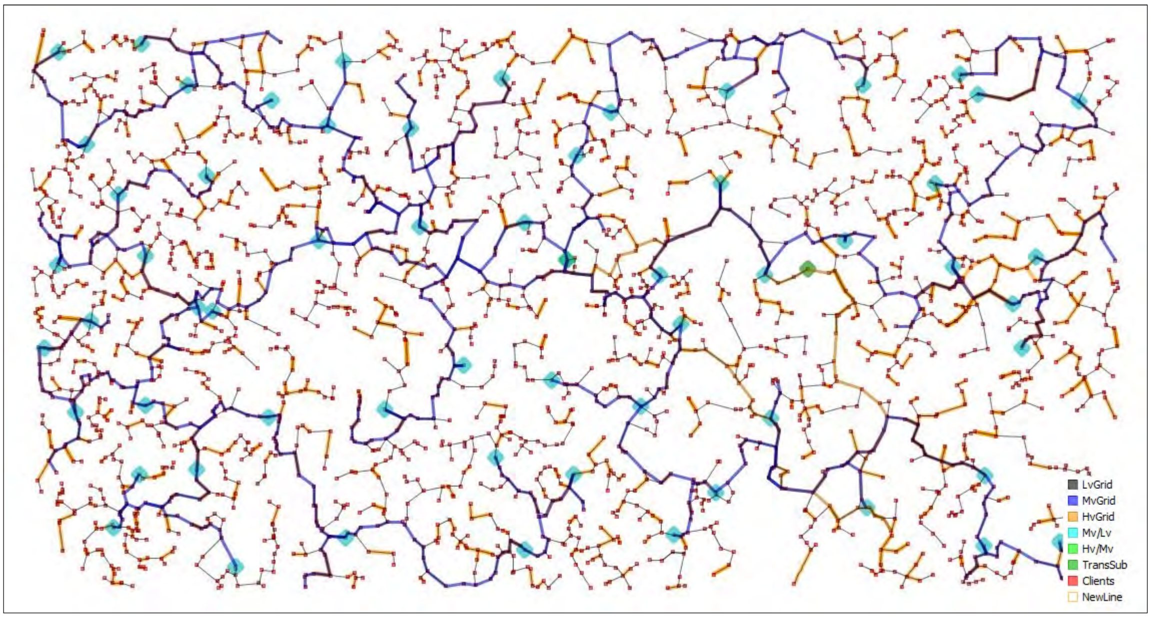

Figure 29: Urban incremental network for 100% adoption

In this case it can be useful to value the differences in terms of the additional equipment needed in the incremental networks for the different levels of adoption. The detailed costs are detailed in Tables 4 and 5.

Adoption	Increment	Cost (€)
3%	LV lines	36154
35%	LV lines	3085
100%	LV lines	318

Table 4: Detailed costs for rural network

Adoption	Increment	Cost (€)
3%	LV lines	99300
	MV lines	178877
	Breaker	29400
	Switch	700
35%	LV lines	50329
	Breaker	29400
100%	LV lines	39678
	Breaker	29400

Table 5: Detailed costs for urban network

As shown in Table 4 the increments on the network are always on the LV network in the rural scenario. In the urban scenario if there is enough adoption, 35% or over, MV increments are not necessary producing important savings in the network costs.

7.4.Distribution of clients with demand response

Finally, the last factor being analyzed is the distribution of the customers with demand response programs as explained before. Peak demand cost is included with 20% of elasticity and 35% of demand response adoption. The results are shown in Figures 30 and 31.

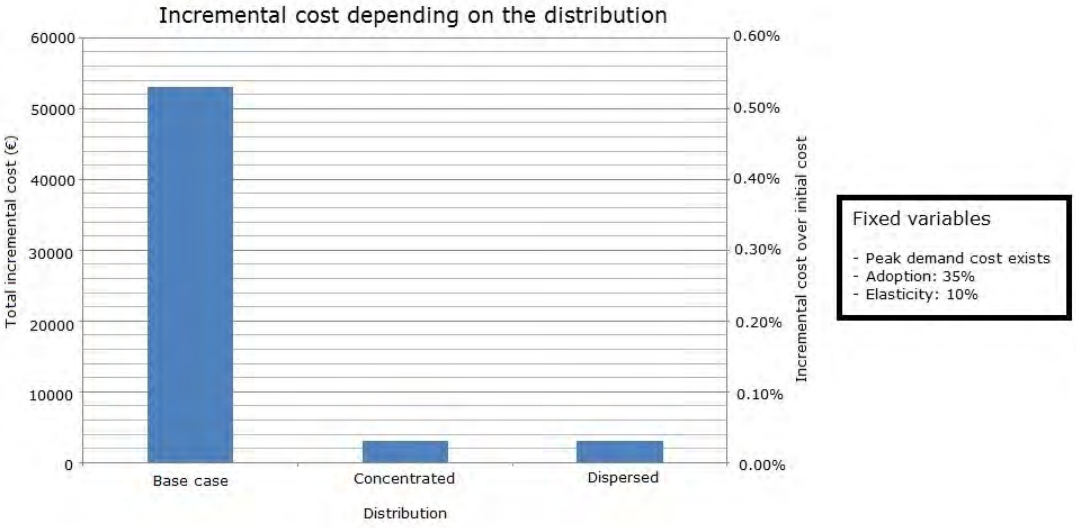

Figure 30: Rural distribution study

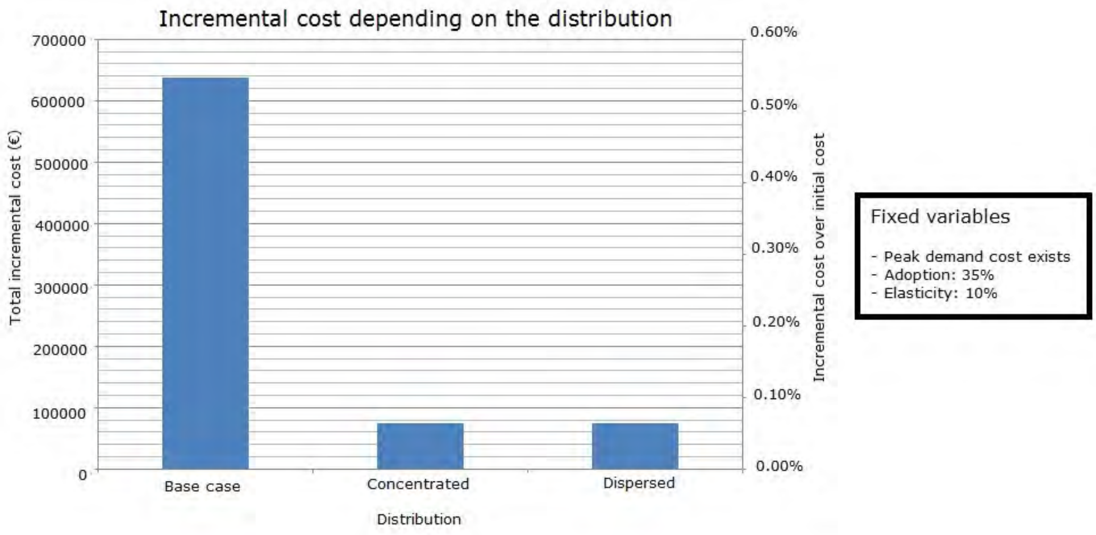

Figure 31: Urban distribution study

As conclusion, it can be concluded that if the concentration of the consumers with demand response adoption is not bigger than 50%, which is the case defined as concentrated, then the incremental network costs won't be different compared to the consumers' randomly distribution case.

8. Conclusions

Different study cases have been carried out depending on the different parameters reported previously.

The first study case is the determination of the peak demand cost impact on total incremental cost. It is concluded that in Spain the inclusion of that extra cost is something positive as it produces two consequences that turns the peak demand cost into something positive:

- Incremental networks are smaller and cheaper while bigger networks are planned when peak demand cost is not considered.
- Consumers' electrical bills are significantly reduced when peak demand cost exists, encouraging the costumers to participate on demand response programs.

The second study case is the determination of elasticity impact on total incremental cost. It can be concluded that the increment on elasticity is something positive since it reduces incremental network costs but when reaching a level of elasticity the costs are not reduced more.

The third study case is the determination of the impact of the number of demand response adopting consumers on network costs. It is concluded that a small adoption like a 3% of the consumers already produces an important impact on costs and when reaching certain adoption, 100% for rural scenario and 35% for urban scenario, incremental costs are almost reduced to zero.

To conclude, a study of the impact on network costs of the distribution of the clients under demand response programs is carried out and it can be concluded that if the concentration of the consumers with demand response adoption is not bigger than 50%, which is the case defined as concentrated, then the incremental network costs won’t be different compared to the consumers’ randomly distribution case.

9. References

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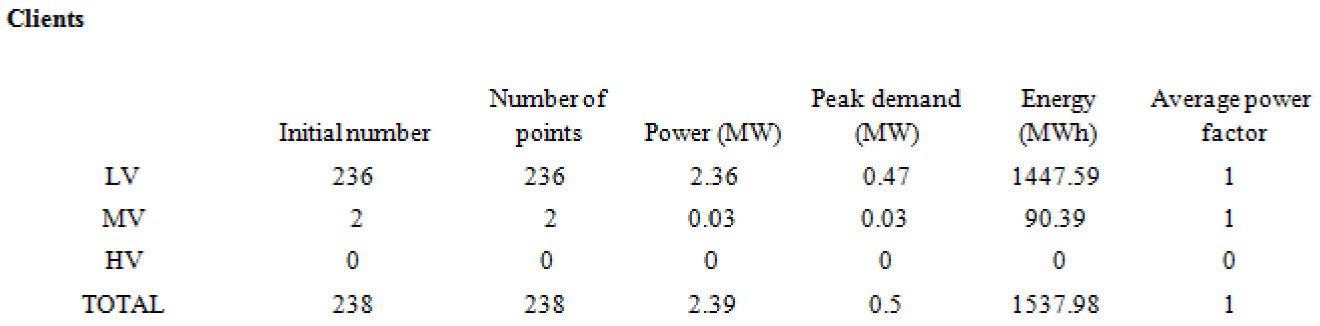
10. Annexes

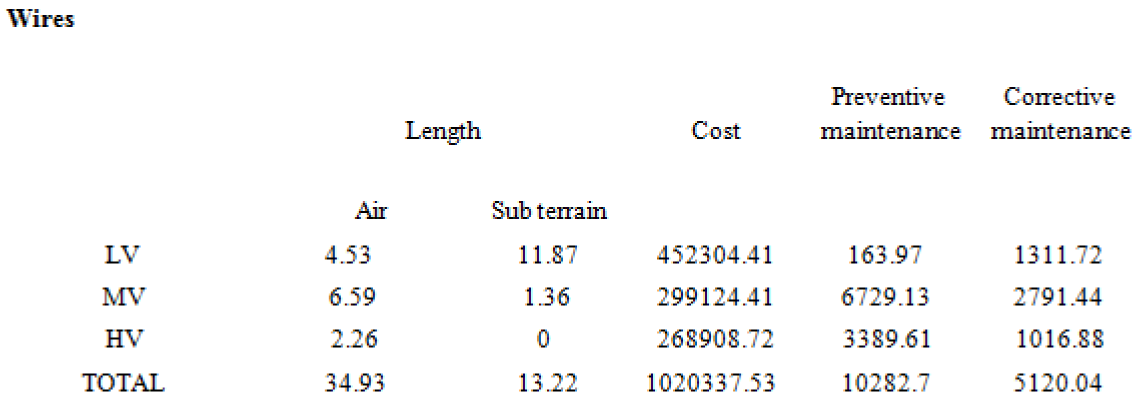
10.1. Annex 1: Initial rural network

The main features of the initial rural network are exposed next. In this document it is collected the results of running the Greenfield Model.



Clients

	Initial number	Number of points	Power (MW)	Peak demand (MW)	Energy (MWh)	Average power factor
LV	236	236	2.36	0.47	1447.59	1
MV	2	2	0.03	0.03	90.39	1
HV	0	0	0	0	0	0
TOTAL	238	238	2.39	0.5	1537.98	1



Wires

	Length		Cost	Preventive maintenance	Corrective maintenance
	Air	Sub terrain			
LV	4.53	11.87	452304.41	163.97	1311.72
MV	6.59	1.36	299124.41	6729.13	2791.44
HV	2.26	0	268908.72	3389.61	1016.88
TOTAL	34.93	13.22	1020337.53	10282.7	5120.04

TS and Substations HV/MV

	Number	No-load losses (MW)	CC loses (MW)	Demand (MVA)	Power (MVA)	Cost	Preventive maintenance	Corrective maintenance
TS	6	0	0.01	0.47	0.75	131500	7000	170
Substations AT/MT	1	0.02	0	0.5	20	2800000	50000	200

Distribution network costs

	Cost		Preventive maintenance			Corrective maintenance		TOTAL (VAN)	
	euro	%	euro	%	hours/year	euro	%	eur	%
LV	11499917.78	23.76	163.97	0.24	16	1311.72	23.89	1178233.97	19.2
TS	131500	3.33	7000	10.4	102	170	3.1	259139.96	4.22
MV	490404.87	10.13	6996.47	10.36	48	2791.52	50.85	662528.82	10.8
Subst. AT/MT	2800000	57.84	50000	74.02	230	200	3.64	3689384.48	60.13
HV	268508.72	5.56	3389.61	5.02	9	1016.88	18.5	346387.24	9.93
TOTAL	4840731.73	100	67550.04	100	405	5490.12	100	6135674.47	100

Losses

	Year 0 losses				Year N losses			
	Energy (MWh)	%	Power (MW)	%	Energy (MWh)	%	Power (MW)	%
LV	49.45	22.16	0.03	51.64	73.48	28.91	0.04	57.9
TS	32.79	14.7	0.01	18.36	39.48	15.53	0.0	19.1
MV	0.49	0.22	0	0.51	0.72	0.28	0	0.57
Subst AT/MT	140.37	62.9	0.02	29.49	140.47	55.27	0.02	22
HV	0	0	0	0	0	0	0	0
TOTAL	223.09	100	0.05	100	254.15	100	0.07	10
Losses respect to demand	14.51%		10.90%		16.52%		14.43%	

Trenches, wall mounts and posts

	Length (km)				Cost			
	Wall mounts	Post	Trench	Total	Wall mounts	Post	Trench	Total
LV	0	0	11.63	11.63	0	0	697613.37	697613.37
MV	0	1.97	0.32	2.29	0	25624.47	31986.22	57610.69
HV	0	0	0	0	0	0	0	0
TOTAL	0	1.97	11.95	13.92	0	25624.47	729599.59	755224.07

Summary of equipment

Installation	Name	Sn(kVA)	Reliability	Number	Average ratio D/Power (pu)	Power (MVA)	Cost
TS	CT_L_02	25	C	2	0.46	0.05	22500
TS	CT_L_04	100	C	2	0.349	0.2	48200
TS	CT_LS_05	250	C	2	0.759	0.5	60800

Installation	Name	Sn(kVA)	Reliability	Number	Average ratio I/Imax (pu)	Length (km)	Cost (euros)
LV_Line	BT_P_01	69	C	25	0.05	4.25	68047.4
LV_Line	BT_P_02	104	C	1	0.06	0.28	5611.46
LV_Line	BT_S_02	121	C	190	0.15	10.88	339542.79
LV_Line	BT_S_03	177	C	12	0.46	0.61	22591.65
LV_Line	BT_S_04	225	C	5	0.57	0.36	14876.51
LV_Line	BT_S_05	291	C	3	0.7	0.01	334.6

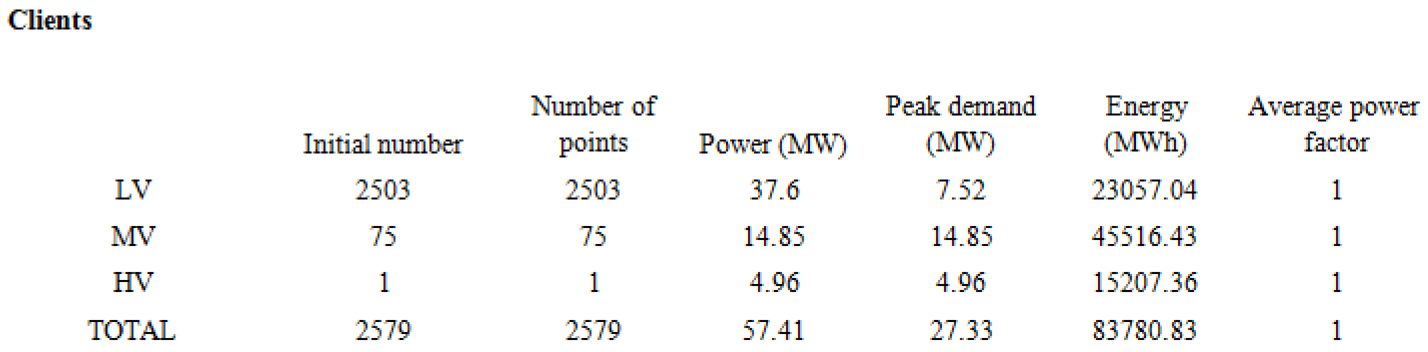
Installation	Name	Sn(kVA)	R	Nu	I/Im	Length (km)	Cost
MV_Line	MT_A_02	6582	S	6	0.02	6.59	187652.3
MV_Line	MT_S_02	6928	S	2	0.01	1.36	81472.11

Installation	Name	Sn(kVA)	Reliability	Number	Average ratio I/Imax (pu)	Length (km)	Cost (euros)
HV_Line	AT_A_H1	66	X	1	84.3	2.26	268908.72

Installation	Name	Sn(kVA)	Reliability	Number	Average ratio D/Power (pu)	Power (MVA)	Cost (euros)
Substation	SEI3	20	C	1	0.025	20	2800000

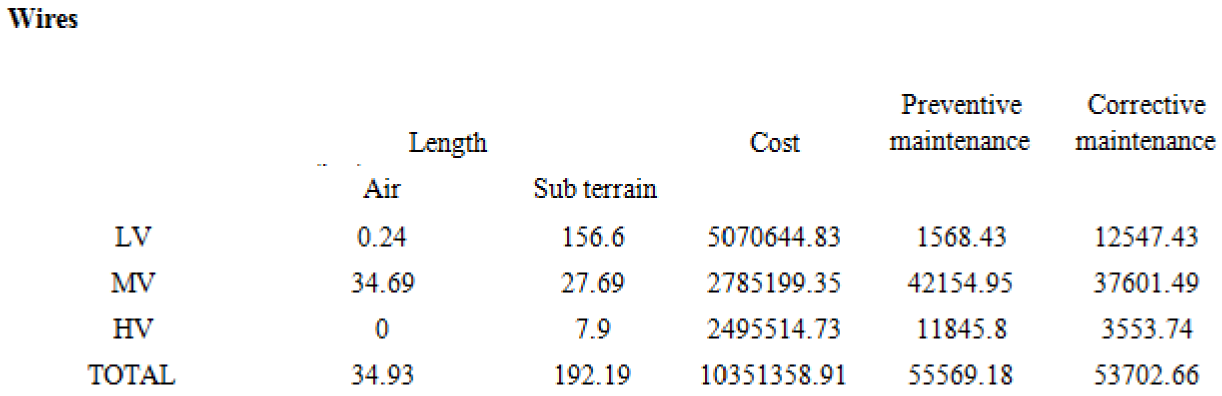
10.2. Annex 2: Initial urban network

The main features of the initial urban network are exposed next. In this document it is collected the results of running the Greenfield Model.



Clients

	Initial number	Number of points	Power (MW)	Peak demand (MW)	Energy (MWh)	Average power factor
LV	2503	2503	37.6	7.52	23057.04	1
MV	75	75	14.85	14.85	45516.43	1
HV	1	1	4.96	4.96	15207.36	1
TOTAL	2579	2579	57.41	27.33	83780.83	1



Wires

	Length		Cost	Preventive maintenance	Corrective maintenance
	Air	Sub terrain			
LV	0.24	156.6	5070644.83	1568.43	12547.43
MV	34.69	27.69	2785199.35	42154.95	37601.49
HV	0	7.9	2495514.73	11845.8	3553.74
TOTAL	34.93	192.19	10351358.91	55569.18	53702.66

TS and Substations HV/MV

	Number	No-load losses (MW)	CC loses (MW)	Demand (MVA)	Power (MVA)	Cost	Preventive maintenance	Corrective maintenance
TS	60	0.03	0.11	7.52	12.3	1675500	90000	1800
Substations AT/MT	1	0.03	0.12	22.37	40	5740000	50000	200

Distribution network costs

	Cost		Preventive maintenance			Corrective maintenance		TOTAL (VAN)	
	euro	%	euro	%	hours/year	euro	%	euro	%
LV	14232539.33	49.64	1568.43	0.78	157	12547.43	22.52	14520823.65	43.58
TS	1675500	9.43	90000	46.02	1020	1800	3.23	3312753.94	9.94
MV	3987431.81	13.91	48649.47	24.08	374	37608.04	67.51	5526410.72	16.59
Subst. AT/MT	5740000	20.02	50000	24.74	230	200	0.36	6646484.78	19.95
HV	3037491.83	10.59	11845.8	5.86	27	3553.74	6.38	3309694.58	9.93
TOTAL	28672962.98	100	202063.7	100	1808	55709.21	100	33316167.68	100

Losses

	Year 0 losses				Year N losses			
	Energy (MWh)	%	Power (MW)	%	Energy (MWh)	%	Power (MW)	%
LV	836.56	36.17	0.48	45.13	1243.09	39.37	0.71	46.06
TS	483.1	20.89	0.15	13.77	579.43	18.35	0.2	13.03
MV	465.94	20.15	0.27	25.14	692.37	21.93	0.4	25.66
Subst AT/MT	497.22	21.5	0.15	14.35	598.37	18.95	0.21	13.6
HV	29.95	1.3	0.02	1.62	44.51	1.41	0.03	1.65
TOTAL	2312.79	100	1.06	100	3157.77	100	1.54	100
Losses respect to demand	0.0276		0.0387		0.0377		0.0564	

Trenches, wall mounts and posts

	Length (km)				Cost			
	Wall mounts	Post	Trench	Total	Wall mounts	Post	Trench	Total
LV	0	0	152.7	152.7	0	0	9161894.5	9161894.5
MV	0	54.63	3.18	57.82	0	710212.28	318438.67	1028650.95
HV	0	0	4.52	4.52	0	0	541977.11	541977.11
TOTAL	0	54.63	160.4	215.03	0	710212.28	10022310.28	10732522.56

Summary of equipment

Installation	Name	Sn(kVA)	Reliability	Number	Average ratio D/Power (pu)	Power (MVA)	Cost (euros)
TTCC	CT_L_04	100	S	27	0.626	2.7	650700
TTCC	CT_LS_05	250	S	24	0.601	6	729600
TTCC	CT_LS_06	400	S	9	0.618	3.6	295200

Installation	Name	Sn(kVA)	Reliability	Number	Average ratio I/Imax (pu)	Length (km)	Cost (euros)
LV_Line	BT_P_01	69	S	1	0.03	0.24	3899.7
LV_Line	BT_S_02	121	S	2273	0.15	138.79	4330128.81
LV_Line	BT_S_03	177	S	128	0.42	9.86	363724.09
LV_Line	BT_S_04	225	S	41	0.5	2.82	115538.84
LV_Line	BT_S_05	291	S	60	0.47	5.13	245263.39

Installation	Name	Sn(kVA)	Reliability	Number	I/Imax (pu)	Length (km)	Cost (euros)
MV_Line	MT_A_02	6582	S	68	0.19	30.55	824857.63
MV_Line	MT_S_02	6928	S	62	0.17	25.33	1522035.19
MV_Line	MT_A_04	9699	S	4	0.76	4.14	140690.12
MV_Line	MT_S_04	9699	S	1	0.81	0	0

Installation	Name	Sn(kVA)	Reliability	Number	Average ratio I/Imax (pu)	Length (km)	Cost (euros)
HV_Line	AT_A_H1	66	X	1	84.3	2.26	268908.72

Installation	Name	Sn(kVA)	Reliability	Number	Average ratio D/Power (pu)	Power (MVA)	Cost (euros)
Substation	SEU5	40	S	1	0.559	40	5740000

10.3. Annex 3: rural complete results

The incremental network total investment cost for the different cases of study followed during the carrying out of the project is summarized next.

Peak demand cost	Elasticity	Adoption	Distribution	Investment cost
Yes	10%	0%	Concentrated	53027 €
			Dispersed	53027 €
		3%	Concentrated	53027 €
			Dispersed	46150 €
		35%	Concentrated	44667 €
			Dispersed	45430 €
		100%	Concentrated	2931 €
			Dispersed	2931 €
	20%	0%	Concentrated	53027 €
			Dispersed	53027 €
		3%	Concentrated	46150 €
			Dispersed	46150 €
		35%	Concentrated	3100 €
			Dispersed	3100 €
		100%	Concentrated	333 €
			Dispersed	333 €
	30%	0%	Concentrated	53027 €
			Dispersed	53027 €
		3%	Concentrated	45639 €
			Dispersed	46150 €
		35%	Concentrated	3100 €
			Dispersed	1352 €
		100%	Concentrated	333 €
			Dispersed	333 €
	40%	0%	Concentrated	53027 €
			Dispersed	53027 €
		3%	Concentrated	45639 €
			Dispersed	46150 €
		35%	Concentrated	3100 €
			Dispersed	1352 €
		100%	Concentrated	333 €
			Dispersed	333 €

No	10%	0%	Concentrated	53027 €
			Dispersed	53027 €
		3%	Concentrated	53027 €
			Dispersed	53027 €
		35%	Concentrated	59453 €
			Dispersed	59453 €
		100%	Concentrated	63839 €
			Dispersed	63839 €
	20%	0%	Concentrated	53027 €
			Dispersed	53027 €
		3%	Concentrated	53236 €
			Dispersed	53027 €
		35%	Concentrated	62258 €
			Dispersed	61569 €
		100%	Concentrated	79858 €
			Dispersed	79858 €
	30%	0%	Concentrated	53027 €
			Dispersed	53027 €
		3%	Concentrated	53236 €
			Dispersed	53236 €
		35%	Concentrated	65009 €
			Dispersed	70150 €
		100%	Concentrated	87328 €
			Dispersed	87328 €
	40%	0%	Concentrated	53027 €
			Dispersed	53027 €
		3%	Concentrated	53236 €
			Dispersed	53236 €
		35%	Concentrated	66804 €
			Dispersed	72574 €
		100%	Concentrated	101120 €
			Dispersed	101120 €

10.4. Annex 4: urban complete results

The incremental network total investment cost for the different cases of study followed during the carrying out of the project is summarized next.

Peak demand cost	Elasticity	Adoption	Distribution	Investment cost
Yes	10%	0%	Concentrated	638039 €
			Dispersed	638039 €
		3%	Concentrated	626765 €
			Dispersed	620957 €
		35%	Concentrated	137378 €
			Dispersed	139791 €
		100%	Concentrated	51486 €
			Dispersed	51486 €
	20%	0%	Concentrated	638039 €
			Dispersed	638039 €
		3%	Concentrated	576509 €
			Dispersed	579134 €
		35%	Concentrated	74201 €
			Dispersed	74201 €
		100%	Concentrated	51486 €
			Dispersed	51486 €
	30%	0%	Concentrated	638039 €
			Dispersed	638039 €
		3%	Concentrated	573352 €
			Dispersed	574596 €
		35%	Concentrated	74201 €
			Dispersed	72258 €
		100%	Concentrated	51486 €
			Dispersed	51486 €
	40%	0%	Concentrated	638039 €
			Dispersed	638039 €
		3%	Concentrated	573352 €
			Dispersed	573363 €
		35%	Concentrated	74201 €
			Dispersed	72258 €
		100%	Concentrated	51486 €
			Dispersed	51486 €

No	10%	0%	Concentrated	638039 €
			Dispersed	638039 €
		3%	Concentrated	650019 €
			Dispersed	661539 €
		35%	Concentrated	1071439 €
			Dispersed	1145523 €
		100%	Concentrated	1532520 €
			Dispersed	1532520 €
	20%	0%	Concentrated	638039 €
			Dispersed	638039 €
		3%	Concentrated	668654 €
			Dispersed	682054 €
		35%	Concentrated	1296972 €
			Dispersed	1275869 €
		100%	Concentrated	2096943 €
			Dispersed	2096943 €
	30%	0%	Concentrated	638039 €
			Dispersed	638039 €
		3%	Concentrated	681893 €
			Dispersed	720917 €
		35%	Concentrated	1516068 €
			Dispersed	1455779 €
		100%	Concentrated	Impossible network
			Dispersed	Impossible network
	40%	0%	Concentrated	638039 €
			Dispersed	638039 €
		3%	Concentrated	736849 €
			Dispersed	732709 €
		35%	Concentrated	1727737 €
			Dispersed	1740999 €
		100%	Concentrated	Impossible network
			Dispersed	Impossible network