# Description of Use cases

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| *Investigating Environmental/Economic Trade-Off Solutions for operational od Use case* |
| *This work aims to identify different operational strategies, varying the base configurations in terms of size of power plants and storages, for Soria use cases with a primary objective to find a balance between environmental sustainability and economic viability.*  *The use case is centred around optimized design configurations incorporating Renewable Energy Sources (RES), Distributed energy sources (DERs) and energy storages.*  *In particular, the study is based on the several assumptions, following mentioned.*  *Soria use cases is:*   * composed by four different end-users loads: *a hospital, a building with 10 office units, a hotel, and a cluster of buildings with 100 residential units;* * *is connected to external infrastructures such as the electricity distribution network and the gas network, each multi-carrier micro-energy hub is made up of a series of generation, conversion and storage technologies.*   *Information about solar energy is taken from the meteorological on line data;*  *For the simulation, energy prices are built on the end user tariffs, according to the Spanish market behaviour. The other inputs are relative to the average emission factor for grid electricity, and the emission factor for natural gas, fixed to 0.354 kg CO2/kWh, and 0.202 kg CO2/kWh, respectively*  *The costs for each tons of CO2 emitted is equal to 65euro/tCO2.*  Results show the annual energy costs reduction and environmental impacts. |
| ***KPI attributed to the UC***   * *List the KPIs assigned* |
| • KPI\_1 Reduction in total annual cost for Soria  • KPI\_2 Reduction in CO2 emissions  • KPI\_3\_Self consumption |

# Simulation results

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| *Operational Tool* |
| **Input data connection**   * Describe where the input data were derived and provide connection link |
| *The required input data include energy demand of the 4 different users (1 hospital, 10 offices, 1 hotel, and 100 residential units, solar energy availability, prices and emission factors of primary energy carriers, and technical and economic information of energy devices, as indicated in the following.*  ***Energy demand of users***  *The total energy demand, refer to 1 hospital , 10 offices, 1 hotel, 100 residential units, , includes: electricity, and thermal energy An overall schematic framework is reported in fig. 1.*    Figure 1. Scheme of the Energy Load  *The hourly energy rate demand for electricity, thermal energy (is given for arepresentative season days, as shown in Figure 2,)*    Figure 2. Hourly energy rate demand for a representative season day (day51);  ***Solar energy availability***  *Information about solar energy is taken from the meteorological data for Soria. The hourly solar irradiance for each representative season day is evaluated as the average of the hourly mean values of the solar irradiance in the corresponding hour of all days in the relative season and is shown in 3*)    Figure 3 Average hourly solar irradiance profiles for the four representative season days  ***Prices and energy factors of primary energy carriers***  *"Energy prices are determined based on the Spanish market. The hourly electricity prices for each representative day of the season are evaluated using a Time of Use (TOU) tariff, which reflects the market electricity price for each corresponding hour of all days within the given season. We assume that, on day 51, the user will pay an electricity price within a range of 0.65 to 0.85 (as shown in Fig. 3). The unit prices for natural gas are provided in Fig. 4."*  Figure 4 Average hourly electricity price profiles for the four representative season days    Table 1. Unit prices of natural gas for the four representative season days   |  |  | | --- | --- | | Representative cold season day | 0.2302 (€/Nm3) | | Representative cold-mid season day | 0.1185 (€/Nm3) | | Representative hot-mid season day | 0.164 (€/Nm3) | | Representative hot season day | 0.1986 (€/Nm3) |   ***Technical and economic information of energy devices and other inputs***  *The technical and economic information of energy, are reported in table*   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | |  | HP | BAT | PCM |  |  |  | WG | PV | | max kW / module | 50 | 82 | 50 |  |  | Capital cost | 2500 | 2000 | | max kWh (=100%Soc) / module | 286,125 | 82 | 205 |  |  | O&M cost Euro/kWh | 0,012 | 0,01 | | O&M cost/kWh | 0,002 | 0,005 | 0,003 |  |  |  |  |  | | O&M cost / module | 0,57225 | 0,41 | 0,615 |  |  |  |  |  | | Specific capital cost/kWh | 200 | 350 | 83 |  |  |  |  |  | | Specific capital cost/modul | 57225 | 28700 | 17015 |  |  |  |  |  | |  |  |  |  |  |  |  |  |  | |  | WG | PV |  |  |  |  |  |  | | Capital cost | 2500 | 2000 |  |  |  |  |  |  | | O&M cost Euro/kWh | 0,012 | 0,01 |  |  |  |  |  |  | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| ***Baseline configuration description***  *In this section, it is presented the baseline configuration in which we assume that:*  ***Electrical Energy:*** *The electrical energy required is sourced directly from the grid. Moreover, for the analysis, it has been assumed an average emission factor of 0.354 kg CO2/kWh for grid electricity, which is indicative of typical emissions associated with Spanish electricity generation.*  ***Thermal Energy:*** *Thermal energy for heating purposes is provided by a conventional boiler supplied by Natural gas, boasting an efficiency rating of 0.90, which represents an average efficiency of such systems. To calculate the energy content of the natural gas used in the boiler, it has been considered a Lower Heating Value (LHV) of 9.8 kWh/Nm3 for methane (natural gas). Additionally, the emission factor for natural gas combustion has been considered equal to 1.98 kg CO2/Nm3.*  *This reference system plays a pivotal role the analysis, serving as a baseline for subsequent calculations of electrical and thermal energy consumption, energy costs,emissions and more in general for the KPIs evaluation.*  **Simulation environment setup and description**  *The aim of the approach is to increase the use of energy storage and renewable resources of a system, and show how hybrid system increase the overall values.*  **Methodology applied:** *To take both cost and environmental assessments into account, a MOLP problem is formulated, and the goal is to determine the operation strategies for a determinate configuration.*    *The economic objective is formulated as the total annual cost to be minimized. The environmental objective is to minimize the amount of CO2 produced, that depends on directly way from the gas consumed by the boilers and CHPs, and indirectly way from the electricity supplied by from the main grid.*    *Considering 4 representative days of the year (1 for each season), and assuming known the energy demand, the total energy required to meet the demand is also known. By minimizing a weighted sum of the total annual cost and primary energy input, the problem is solved by branch-and-cut. The general mathematical formulation established, and the optimization method provided could be applicable in real contexts, thereby providing decision support to planners.*    *Given the input data, such as end user demand, local climate data, energy prices and technical and economic information, the model allows to obtain their optimized combination, and the corresponding operation strategies through cost and energy assessments.*  *The multi-objective optimization problem is characterized by a single objective function in which economic and environmental aspects are taken into account. In particular, the optimization function is formulated as a weighted sum of the total cost, CTOT, and the total environmental costs, to be minimized: (nbWeight\*Eco\_obj) + (1-nbWeight)\*Env\_obj. The optimized size of DERs is obtained under economic and environmental optimization .*  *For ω=1, the economic optimization is obtained, and the related solution is the one that minimizes the total annual cost. For ω=0, the environmental optimization is obtained, and the related solution is the one that minimizes the total annual CO2 emissions. The problem formulated above is linear and involves both discrete and continuous variables. Branch-and-cut, which is powerful for mixed integer linear problems, is therefore used. The model is implemented and tested by using IBM ILOG CPLEX Optimization Studio Version 12.6. The optimization problem can be solved within 1hours.* Hypothesis In base case,   * *Electricity demand can be satisfied by grid power,* * *Specific capital costs, O&M costs as well as electrical and thermal efficiencies are shown* * *Thermal energy is provided by natural gas,* * *Heating demand can be satisfied by, natural gas boilers,* * *The optimization is carried out on an hourly basis for a representative day per season to reduce the variables number and the model complexity.*   *In the SORIA case:*   * *Electricity demand can be satisfied by grid power, by the electricity provided by PV, by the electricity produced by a PCM and by the electricity discharged from the electrical storage.* * *Specific capital costs, O&M costs as well as electrical and thermal efficiencies are shown* * *Thermal energy is provided by natural gas, heat pump, and by thermal energy discharged from the storage.* * *The optimization is carried out on an hourly basis for a representative day per season to reduce the variables number and the model complexity.*  Decision Variables *In the optimization problem, the decision variables include:*   * *existence, numbers, and sizes of energy devices;* * *operation status (on/off) and energy rates provided by energy devices;* * *capacities of electrical and thermal storage devices;* * *electricity and heat rate input and output to/from electrical and thermal storage devices, respectively;* * *electricity rate bought from the power grid.*   *RESULTS*   1. *Base cases : all energy (electricity and thermal) is provided by the distributed electricity grid and by natural gas boiler.*  |  |  |  | | --- | --- | --- | | Hours | Electricity Loads | Thermal loads | | 1 | 391,7357 | 62,75 | | 2 | 395,1273 | 62,75 | | 3 | 386,8388 | 62,75 | | 4 | 400,3276 | 62,75 | | 5 | 398,2891 | 62,75 | | 6 | 485,7462 | 89,09298 | | 7 | 487,6569 | 608,3333 | | 8 | 515,761 | 1032,779 | | 9 | 559,9459 | 1047,917 | | 10 | 571,9275 | 857,7355 | | 11 | 544,9772 | 744,0641 | | 12 | 505,0424 | 763,9758 | | 13 | 497,5128 | 718,9807 | | 14 | 507,4614 | 719,5689 | | 15 | 539,0572 | 694,4022 | | 16 | 556,815 | 720,157 | | 17 | 548,0093 | 765,2354 | | 18 | 497,7187 | 745,3237 | | 19 | 417,148 | 475,8719 | | 20 | 465,6313 | 601,4552 | | 21 | 512,742 | 491,0096 | | 22 | 508,746 | 296,343 | | 23 | 510,5492 | 151,9263 | | 24 | 500.7 | 32,00482 |  |  |  | | --- | --- | | *Eco Obj value [€]* | *10998.34* | | *ENV, Obj value [€Co2]* | *1560.354* | | *CO2 emitted [kg]* | *18.1* | | *Emission Factor (*Kg Co2/kWh*)* | *0.354 -for the grid*  *0.202 for natural gas* |   *2) It is considered also PV systems and wind, although they are considered fixed load.*  *Under this hypothesis, the newelectricity and thermal loads are shown in Fig.*    Figure 1. Hourly energy rate demand for a representative season day (day51);   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Hours | Electricity load | Thermal Load | HP | Battery | PCM | | 1 | 391,7357 | 62,75 | 62,75 | 0 | 400 | | 2 | 395,1273 | 62,75 |  | 0 | 400 | | 3 | 386,8388 | 62,75 |  | 0 | 400 | | 4 | 400,3276 | 62,75 |  | 400 | 0 | | 5 | 398,2891 | 62,75 |  | 400 | 0 | | 6 | 485,7462 | 89,09298 |  | 400 | 0 | | 7 | 487,6569 | 608,3333 |  | 400 | 0 | | 8 | 514,6485 | 1032,779 |  | 400 | 0 | | 9 | 272,8647 | 1047,917 | 1047,917 | 400 | 0 | | 10 | -477,491 | 857,7355 | 857,7355 | -477,4912611 | 0 | | 11 | -1103,96 | 744,0641 | 744,0641 | -1103,960302 |  | | 12 | -725,245 | 763,9758 | 763,9758 | -725,2450877 |  | | 13 | -860,687 | 718,9807 | 718,9807 | -860,6871509 |  | | 14 | -423,845 | 719,5689 | 719,5689 | -423,8448318 |  | | 15 | -910,68 | 694,4022 | 0 | -910,6803196 |  | | 16 | -930,26 | 720,157 |  | -930,2600021 |  | | 17 | -999,703 | 765,2354 | 0 | 0 |  | | 18 | -114,519 | 745,3237 | 745,3237 | 0 |  | | 19 | 337,5168 | 475,8719 | 0 | 0 | 337,5 | | 20 | 465,6 | 601,4552 |  | 0 | 465,6 | | 21 | 512,742 | 491,0096 |  | 175,8420583 | 336,9 | | 22 | 508,746 | 296,343 | 176 | 508,7460442 | 0 | | 23 | 510,5492 | 151,9263 | 151,9263 | 510,5491936 | 0 | | 24 | 500,7015 | 32,00482 |  | 500,7014806 | 0 |  |  |  | | --- | --- | | *Eco Obj value [€]* | *6479* | | *Env, Obj value [€Co2]* | *721.78* | | *CO2 emitted [kg]* | *710.9* | | *Emission Factor (*Kg Co2/kWh*)* | *0.354 -for the grid*  *0.202 for natural gas* |  1. **KPI Reduction in total annual cost for Soria**   Case base =10998.34  Case (51th day)= 6479  KPI= (10998.34-6479)/10998.34 = 41.1%   1. **REDUCTION CO2 emission**   Case base= 18.06  Case (51th day)= 7.11  KPI= (18.06-7-11)/18.06= 61.6%   1. **KPi= Environmental objective value**   Case base= 156.354  Case (51th day)= 72.78  KPI= (1560.3-721.78)/1560.=53.45%   1. **KPI self consumption**   KPI= ( total electricity produced-total grid buy)/total electricity selfconsuption  In our case this KPI is equal to 1 because total grid buy=0. |