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Comparison of different demand response optimization goals on an isolated microgrid

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ABSTRACT

Demand response (DR) is often studied from the consumer point of view to achieve economic benefits, especially when dealing with prosumers. However, DR may also be promoted by the grid manager to optimize the supply system. This study aims at addressing the impacts of these possible conflicting perspectives, in isolated microgrids in presence of centralized versus local renewable energy (RE) generation.

Terceira Island in Azores is used as case study. First, DR is optimized through genetic algorithms to decrease the grid operation costs. Second, DR is optimized through linear programming to decrease direct prosumer costs, assessing also the corresponding impact on the grid. As output for both, the economic dispatch costs, renewable share and emissions are compared.

Results show that DR optimization from the microgrid point of view lead to 1.9% savings on dispatch costs and emissions, while representing an increase of 5.4% regarding the renewable share. On the other hand, the optimization considering the prosumer interest resulted in 1.3% savings for the islands dispatch costs and a 3.2% increase on the renewable share. As such, although both optimizations lead to better grid management, they still show different impacts, urging a common approach for local RE deployment on isolated systems.

Introduction

Electric energy grids have been facing multiple challenges in the last decades. The integration of different variable renewable energy, increasing demand variability, and the need to plan efficient investments and reduce external dependency pose operation challenges which require innovative solutions.

These solutions can be either on the supply side, by introducing energy storage systems and/or dispatchable renewable energy, so long as they have low marginal costs; or on the demand side, through load managing and control schemes as Demand Response (DR), where a percentage of the load is considered to be flexible or shiftable, within a certain time horizon [1]. With the evolution of energy markets to new paradigms as peer-to-peer energy trading, knowing the outcomes of different energy management paradigms, for the different players, is of extremely importance.

Although historically demand response has served, in first place, the utilities to manage emergency events [2], nowadays it is often studied from the consumer point of view, to achieve economic and energy benefits, and it is mostly implemented by price signals to end-users [3]. Furthermore, with the increase of prosumers, where a consumer is also a producer of electricity, the optimization of DR aims to maximize the use of individual local renewable energy (RE) generation, normally solar photovoltaics [4], reducing grid dependency.

On the other hand, the challenges that energy grids face become exacerbated in isolated hybrid microgrids, where multiple supply technologies coexist to respond to a certain load [5], without having the possibility of exchanging electricity with an interconnected grid. Therefore, in isolated systems, demand response may be centrally promoted by the grid manager, by direct load control, to optimize the economic dispatch of the supply system [6] and achieve higher efficiencies, while saving fuel for backup needs, providing grid resilience and delaying the need of further investments [7].

Verschae et al [1] studied the impact of different approaches to DR with prosumers and the corresponding economic incentives. They found that, from the control point of view, direct load control is the best approach despite the great impacts in the quality of life and the difficulties to be implemented, mainly due to remote control needs. Further, prosumer local aggregation is also studied from a home-to-grid approach, without local renewable generation, nonetheless with DR and

Abbreviations: DR, Demand Response; GA, Genetic Algorithms; GHG, Greenhouse Gases; PV, Photovoltaic Solar energy; RE, Renewable Energy; SC, Self-Consumption; TOU, Time of Use tariff; VRE, Variable Renewable Energy

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storage systems, towards peak shaving, based on a user-expected price.

Mazidi et al [8], seeking to fulfill operational challenges with variable renewable energy through demand response, use a two-stage stochastic function to minimize operational costs. The authors test demand response in different types of consumers (residential, commercial and industrial) and find out that lower operation requirement levels are needed with demand response. Focusing on emissions and operation costs, Nwulu and Xia [9] create a multi-objective dispatch optimization, integrating demand response through a game theory optimization to determine the incentives that must be given to end-user to participate in such programs; main findings relate to an effective decrease on daily demand.

Given that there may not be a complete alignment between consumers/prosumers and grid managers in reducing their operation costs, this may lead to a possible conflict on the load optimization paradigm, whenever the needs of the prosumers do not match the grid managers. Therefore, the aim of this work is to compare the outcomes of different demand response optimization goals on an isolated microgrid, looking at the energy costs for the grid operator and the end-users, finding if these are contrary or if they can meet the same goals.

This work is organized as follows: Section "Methodology" presents the methodology of the study; Section "Terceira Case study" describes the case study; Section "Results and discussion" defines the scenarios and details the results obtained; and Section "Conclusions" presents the conclusions and potential future work.

Methodology

In order to compare the impact on the grid operation of implementing demand response optimization in an isolated microgrid, from either the grid manager or the prosumer point of view, an economic dispatch model was used. This model had been previously developed for Corvo Island [7], in Azores, and was adapted to work with different optimization algorithms for introducing demand response (Fig. 1).

In order to study DR in a scenario with prosumers, the impact of local RE generation systems deployment was firstly studied. For this, a characterization of the context was made in four steps:

- *Prosumer profile* – As the distributed renewable generation was considered to be at the residential level, the prosumer was defined as an average domestic user, taking into account its daily average hourly load profile – depending on the data detail available, one or more aggregated profiles were considered;
- *Flexible loads* – Since the prosumers considered in this work are from the residential sector, the flexible loads accounted were found among the most representative domestic electric equipment that can be deferrable in time – the hourly daily loads were taken into account; these equipment would have to be identified from case to case – in this work, washing and drying machines, and dishwashers, were considered, given their representativeness;

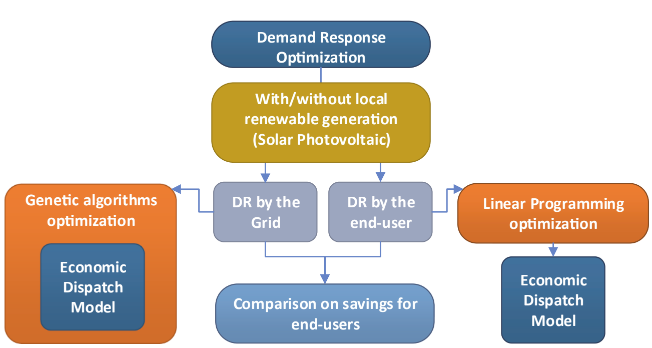

Fig. 1. Models used in the integrated methodology.

- *Local RE generation systems for Self-consumption (SC) and corresponding parameters* – having defined the profile of the domestic prosumer, the parameters related to SC systems were defined as: the rate of its deployment among domestic users, the Photovoltaic Energy (PV) capacity installed, the orientation and tilt of PV systems, and type of electricity tariff;
- *Microgrid energy system configuration* – the island microgrid supply system configuration was also characterized in detail, namely: the generators capacity and load curves, renewable resources availability, operation constraints, as variable renewable energy allowed, start-up/shut down and fuels costs.

As previously explained, the aim of this work was to estimate the magnitude of benefits and the potential alignment of consumer and utilities benefits for both architectures. Thus, as seen in Fig. 1, for computing the benefits of DR, two approaches were taken: from the grid point of view, the optimization was done inside the economic dispatch model function of the microgrid, while for the end-user point of view, the DR optimization was done individually and then included in the microgrid economic dispatch model.

Different demand response optimization strategies were used, according to up-to-date literature [10]. For a centrally managed demand response (grid manager point of view), genetic algorithms optimization was selected since its stochastic nature is expected to have a better performance when dealing with the intermittent nature of variable renewable energy (VRE). Regarding the prosumer DR optimization, a linear programming optimization was chosen since the relation with the structure of costs is linear: the demand is either supplied by PV generation surplus, where the cost is null, or supplied by the grid – where the cost is subject to the hour (off-peak or peak), avoiding in this way more computational effort with more complex algorithms. From each optimization, a flexible load profile was obtained which is used in the islands' economic dispatch model in order to compare the dispatch costs, the renewable share and the GHG emissions.

The optimizations were done for an average day, using hourly definition. Although it can be considered that average profiles are not adequate for assessing self-consumption profiles, this approach aims at reporting the potential of DR, at a first stage, given the lack for more detailed data. The models and their implementation are described in the next subsections.

Economic dispatch model

In this work, an economic dispatch model that combines the unit commitment problem and linear dispatch method was used. The model takes into account the operational restrictions of generation technologies and grid operation, such as minimum up/down time, start-up/shut down costs, operation reserve and variable renewable energy (VRE) allowed in the system. Therefore, the economic dispatch model is a minimization of dispatch costs regarding a certain demand at a certain period h, that evaluates the best transition, from the current state at a given hour to the state at the next hour. The model is represented by Eq. (1):

$$Minimize\,[F_{total}(P_{total})] = \sum_{TU=1}^{N} F_{TU}(P_{TU}) \tag{1}$$

where the objective function F_{total} is the total cost for supplying a certain load (P_{total}), which is the sum of generation cost $F_{TU}(P_{TU})$ of individual thermal unit TU generating a powerP_{TU} (in a total of N).

With the economic dispatch model, economic, energy and environmental parameters, as the production costs, renewable shares, fuel consumption and CO2 emissions are assessed.

Microgrid demand response optimization

The demand response optimization at the microgrid level aims at decreasing the dispatch costs, while increasing the renewable share on the dispatch, and consequently decreasing the associated emissions. To accomplish that, a genetic algorithm (GA) to optimize flexible loads along the island load dispatch, was adapted from [7,11]. Genetic algorithms is a stochastic optimization, first used by J. H. Holland [12], based on natural evolution principles. The main stages of the optimization applied to the described problem are presented next.

Initializing and validation. First, a random population of flexible loads is created: a matrix of dimension *[n × m]* where *n* is the population size and *m* is the number of genes, i.e., the number of time periods under analysis. Each genex_{ij} (matrix entry, being *i* the row entry, and *j* the column entry) represents the amount of shifted power [kW] at each hour.

Each row *i* of the population is a chromosome, where each elementx_{ij}, is subject to certain restrictions, as observed in Eq. (2):

- if the sum of the daily available VRE is higher than the daily flexible loads, then the shifted powerx_{ij}, at each moment, will be a percentage of the available VRE, with the upper limit being the daily flexible loads– this restriction will foster the absorption of VRE through demand response;
- if the totality of the daily available VRE is less than the daily flexible load, then the shiftable powerx_i is just defined as a random percentage of daily flexible loads.

$$\begin{cases} given \quad chromosome = [x_{i1} \quad \cdots x_{ij} \cdots \quad x_{im}] \\ if \sum VRE_j(1{:}\ m) > flexible \quad loads \\ x_{ij} = \%VRE_j;\ 0 \le x_{ij} \le flexible \quad loads \\ else \\ x_{ij} = \%flexible \quad loads \end{cases} \tag{2}$$

Cost function and penalties. The cost function consists in minimizing the economic dispatch costs considering the unit commitment problem, taking into account various operational constraints of the generating technologies, such as generators' start-up and shut-down costs, minimum up and down time, ramp up/down rate, minimum power output and operating reserve, and VRE, as introduced in [7]. The flexible load profile is summed to the island hourly load and tested on the dispatch model. The dispatch function optimizes the commitment of the available generators, at each hour, for a given demand, checking the feasibility of the transitions of each state of commitment. The model works with an hourly time-step, and returns the overall dispatch costs, diesel consumed, CO_2 emissions and renewable share.

To guarantee that flexible loads are shifted in totality (since they represent work cycles of certain household's equipment), after running the economic dispatch model, different penalties are introduced to the dispatch costs, in case the total shifted loads do not meet or exceed the daily flexible loads. A higher penalty is given in case the shifted loads are lower than the flexible loads, since it would mean that the working cycle of some flexible equipment would not be completed, thus leading to a decrease on the users' comfort. If the total shifted loads are equal to the flexible loads, no penalty is given (Eq. (3)). The penalties described are applied to the output of the cost function.

$$\begin{cases} if \sum_{j=1}^{m} x_{ij} < flexile \quad loads \to penalty = p^2 \\ if \sum_{j=1}^{m} x_{ij} > flexible \quad loads \to penalty = \frac{1}{2}p^2 \\ f \sum_{j=1}^{m} x_{ij} = flexible \quad loads \to penalty = 0 \end{cases} \tag{3}$$

where p is a penalty factor defined by $p = 10$.

Selection, Cross-over and mutation. The particularity of genetic algorithms is that they undertake natural processes such as selection, cross-over and mutation [13]. In this work, the selection process used was the tournament wheel, with a tournament size of 2, since it is widely used for minimization problems. Afterwards, the cross-over was applied with the single point cross-over method and with a probability of cross-over of 70%. Finally, mutation was also applied in this context, using uniform mutation with a probability of 5%.

Iterations on population and generation. The GA optimization is done through the execution of the mentioned phases through a population and over multiple generations. These parameters are also defined by the user, and a population of 50 and a generation of 100 were used, once they proved to achieve a convergence on the best fitted chromosome. The best fitted chromosome will be the hourly flexible load profile that has the best minimum dispatch cost when dispatched with the island load profile.

Prosumer demand response optimization

At the residential prosumer level, the demand response optimization was done in order to reduce the prosumer electricity costs due to electricity purchases from the grid. In this way, a linear programming optimization strategy was used (*linprog Matlab* function) to guarantee that the flexible loads managed through demand response take full profit of solar generation and time of use (TOU) tariff, which was considered as dual tariff (peak and off-peak prices). The problem was posed from an aggregated point of view, considering the total number of domestic prosumers, since the profiles considered were also averaged domestic profiles.

As such, the minimization problem of the prosumers cost function $f(x)$ and its constraints are described by Eq. (4):

$$\begin{cases} \min[f(x)] = \sum_{j=1}^{24} a_j x_j \\ \sum_{j=1}^{24} x_j = Daily \quad flexible \quad needs \\ if PVgen(j) > fixed \quad demand(j) \to x_j \le PVgen(j) - fixed \quad demand(j);\ a_j \\ = 0 \\ else \to x_j \le \max DR; \\ a_j = offpeak \quad price \quad for \quad j = [22h - 8h]; a_j = peak \quad price \quad for \quad j \\ = [8h - 22h] \\ 0 \le x_j \le \max DR \end{cases} \tag{4}$$

where:

- j is the hour of the day;
- $x_j$is the energy of backup for a certain group of users, for a certain hour;
- a_j is the cost of the kWh imported from the grid, at certain hour;
- $\max DR$ is the maximum shiftable load at each hour.

The profile that results from the prosumer optimization was then tested on the islands economic dispatch model.

Terceira case study

Context and electricity demand

Terceira Island is located in the Azores archipelago, Portugal, in the mid-Atlantic Ocean. It has a population of approximately 56 000 inhabitants and represents around 25% of the Azores energy demand. The main economic activities are agriculture, fishing and commerce, while the main electricity consumer is the residential sector, which accounts for approximately 31% of the island's electricity demand.

The island's average hourly load profile is presented in Fig. 2. Terceira annual demand accounts for 192 GWh, with a maximum peak power of around 34 MW. While the total island's load was accessed

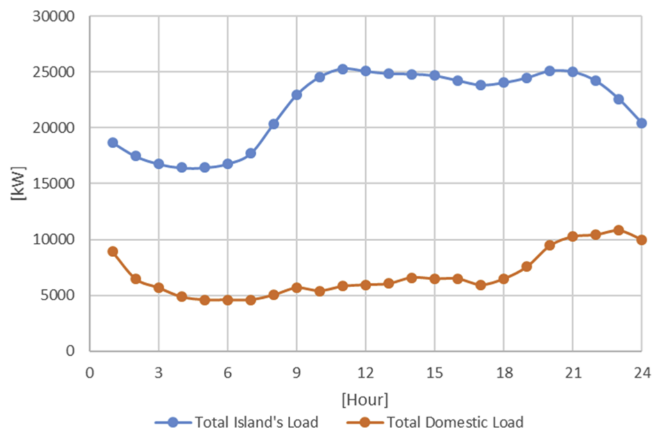

Fig. 2. Terceira total and domestic average load profile.

from annual hourly data, the domestic profile was synthetized from [14] using the domestic daily value of electricity demand in Terceira [15].

The electricity generation in Terceira is mainly from thermal power plants, but there is a significant share of endogenous and renewable resources being explored. Hydro is the oldest renewable resource explored in the island albeit having a small production index, while wind has a significant power installed (two power plants), giving the highest RE contribution for the supply. Furthermore, investments were also recently made on residual waste and geothermal power plants, as presented in Table 1.

Demand response potential

When looking for possible flexible loads at the residential level, to perform demand response, the domestic equipment in Azorean homes was analyzed [17]. The average domestic consumer has an annual demand of 2471 kWh/year. The most frequent equipment and with demand response potential is the washing and drying machines and the dishwasher, with a respectively share of 94%, 55% and 27% on the houses. According to the profiles synthesized from [14], the load profiles of the referred domestic equipment are presented in Fig. 3a) in detail, and in Fig. 3b) compared to the total residential demand.

Therefore, the sum of the three flexible equipment of Terceira's households represents a percentage of flexible loads of 6% of the island's total load and will define the maximum shiftable load previously presented in Section "Prosumer demand response optimization".

Segmentation of domestic consumers

In order to consider some demand variability, statistical data about family types in Terceira was consulted, namely the number of persons and age [18]. The families (24257 domestic users) were aggregated in three representative domestic consumers:

- *Demand1* – One person living alone or a couple;
- *Demand2* – One adult or a couple plus one, two or three little children;
- *Demand3* – A couple plus one, two or three adults (teenagers, young adults or grandparents).

Table 1
Terceira Power plants and installed capacity [16].

Power Plant	Thermal	Wind	Hydro	Geothermal	Waste
Installed Capacity [MW]	61.2	12.6	1.4	3.0	1.8

Table 2 presents the distribution in percentage of domestic consumers regarding each type of typified demand and the annual energy demand by each, according to Terceira Island. Fig. 4 presents the total consumption profiles according to the presented consumers shares.

The profiles presented in Fig. 4 were obtained through real data [19] and normalized for Terceira domestic consumption. As can be observed, *Demand1* and *Demand2* are characterized by a low demand during the day with a night peak, with the difference that *Demand2* takes advantage of off-peak hours having higher loads from 22 h to 1 h. On the other hand, *Demand3* presents a more stable load along the day, representing the occupancy of one or more adults.

Self-consumption systems

Nowadays, local RE generation in Terceira has little impact on the overall demand, with an installed capacity of only 38 kW, representing 0.03% of the island's electricity demand. However, as a new national directive was implemented (DL 153/2014) [20], an increase on the deployment of local RE generation systems is expected, in order to increase self-consumption within consumers. These SC systems should be deployed according to each type of consumer, as a way to reduce the prosumer electricity costs.

Analysing the type of domestic consumer profile, a techno-economic analysis study was used to determine the best PV size to be implemented [19]. As such, in this work, an implementation of 500 Wp of self-consumption PV systems with optimum tilt and orientation, in 100% of domestic users is considered. Therefore, a total of 12 MW of distributed solar energy was considered. Even though the domestic users were segmented, the daily demand of each profile is very similar – 6, 7 and 8 kWh/day, respectively to *Demand1, Demand2* and *Demand3*, which explains the same installed PV capacity.

Electricity costs were defined according to Portuguese Energy regulator [21] and are 0.1002 €/kWh during off-peak hours (0 h–8 h and 22 h–24 h) and 0.1909 €/kWh during peak hours (8 h–22 h).

Results and discussion

Scenario definition

To enable a detailed comparison, the following scenarios were defined:

- **Base scenario** – Economic dispatch model simulates the present state of the island (without local RE generation systems or demand response);
- **Scenario 1** – No demand response – Economic dispatch model is applied to the islands total load, considering that PV generation is consumed locally (self-consumed);
- **Scenario 2** – Centrally managed demand response – The optimization described in "Microgrid demand response optimization" section is applied;
- **Scenario 3** – Locally managed demand response – The optimization described in "Prosumer demand response optimization" section is applied, considering different types of domestic users, regarding the family and demand characteristics, being then ran in the economic dispatch model.

Table 3 presents the scenarios comparison and the respective comparison goal.

Impact of local PV generation

Table 4 presents the comparison between the Base Scenario and Scenario1, for an average day, while Fig. 5 shows graphically the impact of self-consumption systems on the island's total load.

As it is seen in Table 4, local PV generation induces a rate of self-

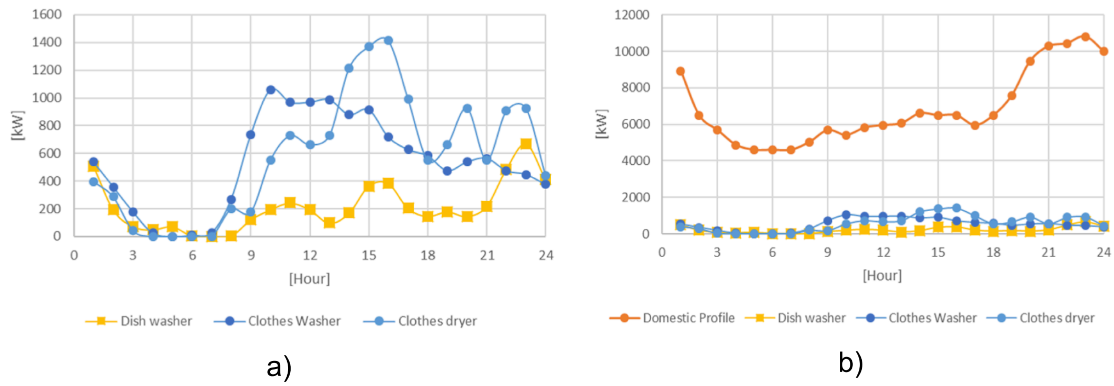

Fig. 3. a) Domestic equipment load profiles; b) Equipment's share in the island's domestic sector load.

Table 2
Terceira domestic users' segmentation.

Typified Demand	Number of consumers [%]	Annual demand [kWh/year]
Demand1	38%	2190
Demand2	47%	2555
Demand3	15%	2920

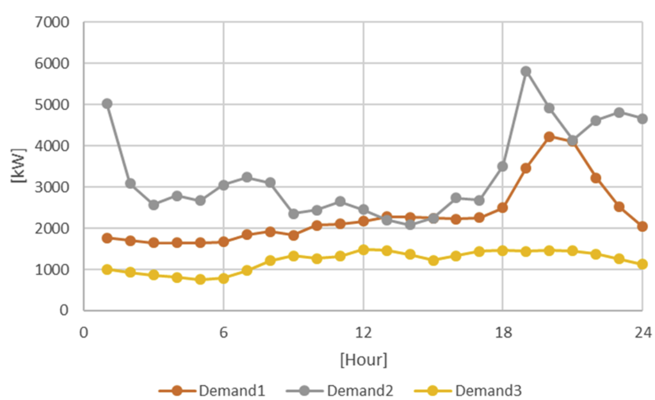

Fig. 4. Profile shares of segmented domestic users.

Table 3
Scenarios comparison.

Comparison			Goal
Base Scenario	vs	Scenario1	Impact of PV self-consumption
Scenario1	vs	Scenario 2 & Scenario3	Impact of different DR optimization objectives

consumption (energy produced and generated locally) of around 9%, similar to the decrease in the energy import from the grid, since grid losses are neglected. This leads to a decrease in the dispatch costs of 6.5% per day, with equal decreasing rates for fuel consumption, albeit the specific emissions increase in 3%. Furthermore, the peak demand reduces by only 1%, which, as observed in Fig. 5, results from a shift of the daily peak at 10 h to an evening peak at 20 h. The island's load, which was mainly flat, becomes more "hilly" with a morning and evening peaks with the effect of solar production. Further, besides the introduction of local RE generation, the share of renewable generation in the "new load" profile increases by 1.6%.

For the domestic users, local PV generation induces different savings that go from 122 €/year for *Demand2* to 138 €/year for *Demand3*. From the economical point of view, it is more advantageous for *Demand3* users, mainly due to the occupancy that exists during the day, taking advantage of the diurnal PV generation.

Table 4
Scenario comparison for the impact on the grid of local PV generation for self-consumption.

	Units	Base Scenario	Scenario1 – PV only	Δ
Energy Production	MWh	526.9	478	−9.3%
Production cost	€	49 806	46 573	−6.5%
Specific CO_2 Emissions	g/kWh	493.8	508.94	3.1%
Fuel Consumption	L	90 870	84 971	−6.5%
Peak Demand	kW	25 294	25 046	−1.0%
Grid Shares				
Thermal	%	64.58	64.02	−0.9%
Total RE	%	35.41	35.98	1.6%
Annual savings for domestic users				
Demand1	€/year	–	133.5	
Demand2	€/year	–	121.8	
Demand3	€/year	–	138.1	

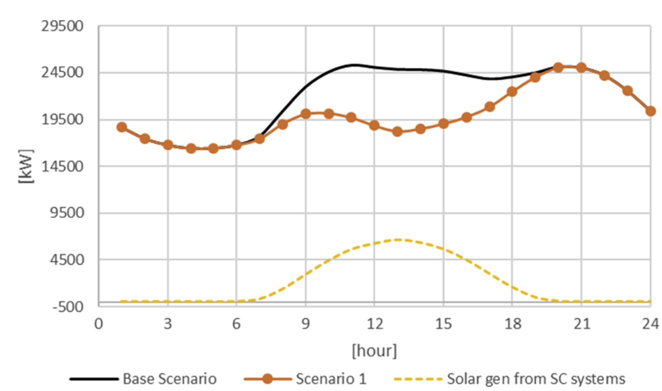

Fig. 5. Impact of Self-consumption systems on the islands load.

Comparison of the impact of demand response

Assessing the impact of demand response with local PV generation from the point of view of different agents (grid manager or end-user), Table 5 presents the comparison between Scenario 1 and Scenarios 2 and 3.

Regarding Scenario 2, where the DR optimization is done from the grid manager point of view, it is observed that the production costs are decreased by 1.9%. Peak demand would reduce by 5.4%, while renewable generation share would increase by 5.4%. In terms of economic savings for the domestic users, when compared with Scenario 1, the savings amount to 10–12 €/year/user, being similar to all types of user.

Looking at Scenario 3, where the DR optimization is done from the prosumer side, Table 5 reports that for the island's dispatch, lower

Table 5
Scenario Comparison for DR impact.

	Units	Scenario 1 – PV only	Scenario 2 – DR GA	Δ	Scenario 3 – DR prosumer	Δ
Energy Production	MWh	478	478		478	
Production cost	€	46 573	45 696	−1.9%	45 943	−1.4%
Specific CO_2 Emissions	g/kWh	508.94	499.35	−1.9%	502.06	−1.4%
Fuel Consumption	L	84 971	83 371	−1.9%	83 822	−1.4%
Peak Demand	kW	25 046	23 683	−5.4%	23 741	−5.2%
Grid Shares						
Thermal	%	64.02	62.08	−3.0%	62.62	−2.2%
Total RE	%	35.98	37.93	5.4%	37.38	3.9%
Annual savings for domestic users						
Demand1	€/year	–	12.25		20.06	
Demand2	€/year	–	12.14		20.05	
Demand3	€/year	–	10.41		27.22	

results are achieved in terms of costs, CO_2 mitigation and on the increase of endogenous resources. In terms of savings for the prosumers, in Scenario 3 they reach 27.22 €/year for *Demand3* and 20 €/year for *Demand1* and *Demand2*.

Looking at Fig. 6, it is observable that while Scenario 1 demonstrates a smoother hourly profile, Scenario 2 presents more oscillations due to taking advantage of the available variable renewable energy, as from the wind energy power plant at certain hours. Concerning Scenario 3, a clear tendency to shift the loads to off-peak hours (when energy is less costly) and irradiance hours (9 h to 17 h – where energy is provided by PV) is noticeable, since these (solar production and off-peak hours) are the only price incentives that individual consumers have to shift their loads.

This indicates that both DR optimizations (Scenario 2 and 3) promote savings to the total electricity system, although at different levels, having largest savings in Scenario 2. However, the prosumer savings found for Scenario 2 (11€/year/user) were found to be very low, when compared to the savings that each user can achieve by himself (Scenario 3), as any incentive for a direct load control agreement between the grid manager and the users, would not be higher than the savings collected from the electricity system.

Still, further research must be pursued in order to understand which type and extend of incentives should be given for users to agree to participate in such programs, since, in this case, the cost savings derived from a more efficient operation might not be enough.

Conclusions

The aim of this work was to estimate the magnitude of benefits and the potential alignment of consumer and utilities benefits when executing demand response programs. A comparison of demand response optimizations in the presence of local RE generation, for isolated hybrid microgrids, was performed considering different agents, as the grid manager and the end-users. An economic dispatch model, coupled with different optimization algorithms was used to study the impacts of implementing DR at both levels, assessing the dispatch costs, renewable shares and CO_2 emissions. To model the demand response from the grid manager point of view, a genetic algorithm was used to take full profit of centralized renewable generation, while the modelling of the prosumer side was performed using a linear programming algorithm, customized to earn gains in the local PV generation and off-peak tariff.

Terceira Island in Azores was used as case study. A segmentation of the domestic users was made, with three groups of consumers, with specific demand and load profiles having been derived. All domestic users were considered to be prosumers, in order to identify the potential benefits of DR. The loads of washing machines, drying machines and dishwashers were simulated as flexible loads, being shifted in time.

The results show that optimizing controllable loads from the grid manager point of view or from the prosumer point of view can lead to savings on production costs and increase the renewable shares, while reducing peak demand. However, the benefits for the electricity system were found to be slightly higher when the optimization is performed from the grid manager point of view. Conversely, the savings for the prosumers were higher for DR locally optimized, as expected, when compared with the DR centrally managed.

The outcome of this work is valuable for policymaking for isolated microgrids. With the introduction of decentralized renewable generation, and the evolution of smart-appliances, policymakers may want to introduce and test different enabling technologies as energy storage and demand response, as a way to increase security of supply and resilience on isolated microgrids. However, before making such decisions and/or investments, its consequences shall be assessed, to which this study can contribute for an overview of the problem. As the results show that both DR goals provide savings for both grid operator and end-user, a more detailed study should be taken to look into the challenge of its deployment.

Thus, future work may be done in addressing the microgrid operation under these circumstances, and also the willingness of insular population to participate in such programs and their motivation. Moreover, different types of prosumers (industrial, commercial, etc.)

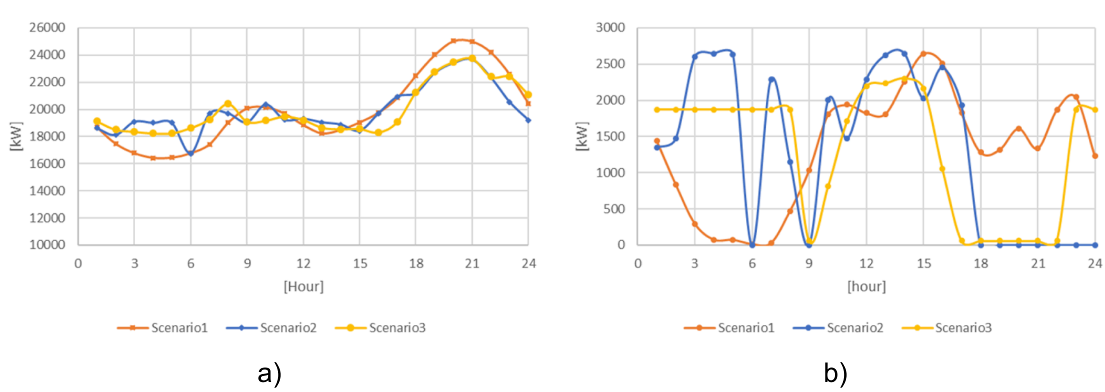

Fig. 6. a) Total Island's load profile comparison; b) Final load profile of equipment with DR.

and different deployment rates should be tested to identify the most beneficial situations.

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