PV Virtual Power Plant: Evaluating the performance of clustered x individual rooftop PV installations

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Abstract

The ANEEL's Normative Instruction (NI) 687/2015 enabled new business models for distributed generation in Brazil. The photovoltaic technology, being easily accessible, has been having a good acceptance and penetration in the Brazilian residential market. The objective of this paper is to simulate the clustering of multiple photovoltaic micro-generators through a cooperative and to analyze the productivity of a virtual decentralized power plant: 20 clustered individual rooftop PV installations – a PV virtual power plant (PV-VPP) – applied to homes in the state of Santa Catarina, Brazil, and in the concession area of the same distribution utility. The PV-VPP is a group of small PV generators, which work collectively and collaboratively, and which adheres to the Brazilian regulatory requirements. This case-study analyzes the home consumptions and then simulates the application of building applied PV (BAPV) system on rooftops. The analysis shows the individual performance for each residence and its performance when it is associated in a PV-VPP. This paper concludes that a cooperative without any distinction from its members or previous evaluation can bring positive or negative influence on each cooperative member. When analyzing the annual PV generation, the results show differences between the two studied situations (clustered or individual), ranging between from -14% to +25%. The units that do not have azimuth deviation contribute to the greater efficiency of the cooperative, since there was a reduction of their clustered generation in relation to the individual. The impact portion was distributed among the units, reducing the risk of an individualized unit, thus seeking greater group stability.

Keywords: Photovoltaics, Shared Economy, VPP, Community Solar, Distributed Generation

1. Introduction

The Brazilian distributed generation (DG) market to small prosumers began in 2012, with the approval of the ANEEL's Normative Instruction (NI) 482/2012, which created and regulated a net metering scheme in Brazil, the so called Electrical Energy Compensation System (EECS), so that the investor in DG can use the generated energy credits. Thereafter, in 2015, the publication of NI 687/2015 authorized projects with multiple consumer units, shared generation and remote self-consumption. The instruction paved the way to business model development in shared generation in the country. Stakeholders can join in a consortium or cooperative, aiming to produce their own energy through a micro (up to 75 kW) or mini (between 75 kW and 5 MW) generation distributed system. With the massive price reductions experienced by the photovoltaic (PV) technology in recent years, rooftop PV generation is increasingly accessible to Brazilian consumers, partly due to DG systems whose economic viability in Brazil has been made possible through EECS.

The concept of shared economy contributed to the business model's emergence on renewable energy generation, such as shared solar PV. The emerging conditions of these models are specific to the context of each country, depending on policies, regulations, incentives and market conditions (Noll et al., 2014; Augustine and Mcgavisk, 2016; Tongsopit et al., 2016; Briguglio and Formosa, 2017; Deng and Newton, 2017; Hancevic et al., 2017; Matisoff and Johnson, 2017). Cooperatives for sharing energy credits create an opportunity to strengthen the links between consumers and suppliers. A DG cooperative consists of the union of a group of people, aiming to produce their own energy and which depend on each other to enable their common interest. In Brazil, the minimum group to form a cooperative is 20 people, according to the

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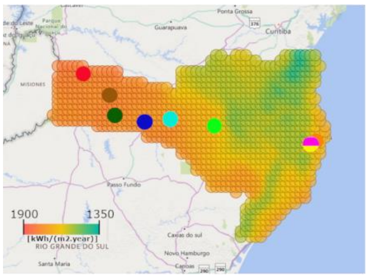
Organização das Cooperativas Brasileiras (OCB).

This paper evaluates the impacts of a DG cooperative (that is also a PV-VPP) composed by 20 generating units (homes), distributed along the state of Santa Catarina, Brazil, and supplied by the same distribution utility, but with different solar irradiation conditions and different PV installed power per home. Each home is analyzed and compared working by itself and integrated into a cooperative group. The results show PV generation performance for each home in two scenarios: clustered (PV-VPP, PV cooperative) or working individually.

2. Method

This research was developed in four stages: (i) Data collection and information; (ii) Simulation of individual generation; (iii) Simulation of the cooperative (VPP) generation; (iv) Comparison between individual local production and aggregated production (VPP, cooperative) in a decentralized way.

The data and information used were obtained from a previous research (Antoniolli, 2016), which made a technical and economic evaluation between Building Applied PV (BAPV) system and ideally installed PV systems in south Brazil, in the state of Santa Catarina, Brazil. Data were obtained from 20 homes distributed in nine cities throughout the state. Figure 1 shows the location of each city on Santa Catarina map, their coordinates and the average annual of Global Horizontal Irradiation (GHI).



Location	Coordinates		GHI
	Longitude	Latitude	[kWh/(m2.year)]
Florianópolis	-48.56	-27.58	1544
São José	-48.65	-27.63	1512
Palhoça	-48.66	-27.63	1511
Curitibanos	-50.60	-27.30	1585
Joaçaba	-51.50	-27.17	1649
Concórdia	-52.02	-27.23	1675
Chapecó	-52.61	-27.08	1694
Quilombo	-52.72	-26.73	1694
Palma Sola	-53.26	-26.34	1703

Figure 1: Geographic location and irradiation for each city.

With the energy consumption data, as shown in Figure 2, it was possible to calculate a PV power required and estimate the generation for each home. Note that the annual consumption values for the evaluated homes are between 1,318 and 11,648 kWh/year.

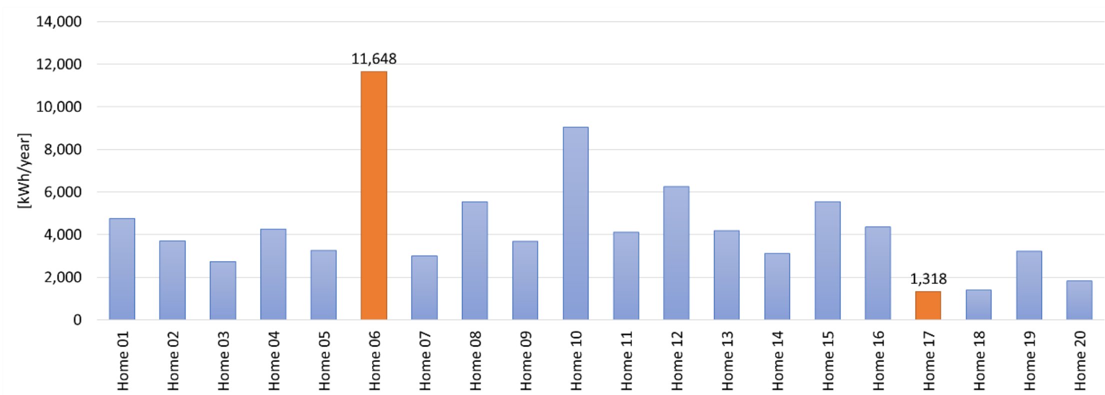


Figure 2: Annual energy consumption for each individual dwelling evaluated in this study.

The PV power required analyses were performed considering the architectural characteristics of each rooftop (each BAPV system). As described by Antoniolli (2016), the calculations of tilted irradiation on the plane of BAPV array were based into the global solar irradiation data from the Solar and Wind Energy Resource

Assessment project SWERA (Pereira et al., 2006). This Paper uses updated irradiation data, based on the new version of the Brazilian Solar Energy Atlas (Pereira et al., 2017).

The first BIPV (building-integrated PV) system installed in Brazil is placed in Florianópolis (27º S; 48º W), it was designed and installed in 1997 by Fotovoltaica-UFSC (www.fotovoltaica.ufsc.br), and it has been monitored since then (Rüther, 1998; Rüther and Dacoregio, 2000). The system is ideally oriented (27° tilt, facing North), based on amorphous silicon (a-Si) modules, and it has been operating without interruptions with an annual Yield of 1,100 kWh/kWp and a PR averaging from 70 to 80% (Rüther et al., 2010). Therefore, in this paper, the Yield [kWh/kWp] for each BAPV system was linked to a performance ratio (PR) of 80% (Reich et al., 2012), and the installed PV modules characteristics are: multi-crystalline silicon technology, 15.85% efficiency and 250 Wp nominal power.

Based on PV power required for each home, the amount of PV modules was determined, which served as a parameter for the calculation of PV adjusted power.

In this paper, Yield is linked to the characteristics of each BAPV system, such as location, useful area, rooftop tilt and orientation. This terminology allows to compare systems with different installed PV power, because, this way, it is possible to have the same information for each system in the same scale and unit, regardless of the size or location of the systems being evaluated (Marion et al., 2005; Antoniolli et al., 2014). Thus, it was possible to compare 20 different generating units that were later joined into a DG-PV cooperative (that woks like a PV-VPP).

For the cooperative generation, an aggregator was used to link each individual BAPV system with a totalizer of the cooperative (VPP) generation. Thereafter, a power distribution quota was defined by the cooperative through a percentual share, with each cooperative quota unit corresponding to each PV module installed. Each cooperative member receives its generation share proportional to the quota participation. Thus, it was possible to analyze the clustering of multiple microgenerators operating in a decentralized manner and with the management model of a VPP. The reason to adopt quotes per PV modules was because the NI 482/2012 and NI 687/2015 don't approve to link any energy generation units to define quotas.

Each BAPV system has a specific Yield, due to the tilted irradiation on the plane of BAPV array. The overall cooperative Yield is represented by the annual generation sum of the 20 BAPV systems, divided by the PV power sum of the 20 BAPV systems. Therefore, Yield is the central equivalence reference among the systems.

The comparative of the individual Yield from each cooperative member is presented through the quota system, aiming to identify the impacts of joining the solar cooperative.

2.1. Individual analysis

The comparison between two systems (individual and clustered) was based on Yield and PV energy generation.

Eq. 1 is used to calculate Yield (Y):

$$\mathrm{Y} = PR \times \frac{G_{POA}}{Irr_{STC}} \qquad \text{(eq. 1)}$$

Where:

Y = Yield of the BAPV system [kWh/(kWp·year)]

PR = Performance Ratio in an annual base (Marion et al., 2005) = typically 80% (Reich et al., 2012; Rüther et al., 2010)

G_{POA} = Global irradiation on the plane of BAPV array [kWh/(m²·year)]

Irr_{STC} = Irradiance under Standard Test Conditions = 1 kW/m²

Eq. 2 is used to estimate the PV power required of each home:

$$P_{PV} = \frac{Consumption}{Y} \qquad \text{(eq. 2)}$$

Where:

P_{PV} = Installed PV power required from the BAPV system to fit the house consumption [kWp].

Consumption = Annual consumption of each home [kWh/year]

Y = Yield of the BAPV system [kWh/(kWp·year)]

After identifying the PV power required for each BAPV, a rounding calculation was made according the rated power of the adopted module (multi-crystalline silicon technology, 15.85% efficiency and 250 Wp rated power), obtaining the value of corrected nominal PV installed power (P_{PVC}), this value was applied in Eq. 3 to identify the estimated generation for each system.

$$E_{PV} = Y \times P_{PVC} \qquad \text{(eq. 3)}$$

Where:

E_{PV} = Total energy generation of each BAPV system [kWh/year]

Y = Yield of the BAPV system [kWh/(kWp·year)]

P_{PVC} = Corrected nominal PV installed power [kWp]

2.2. Clustered analysis

The total energy generated by the cooperative is a sum of the individual total of each BAPV system, as shown in Eq. 4:

$$E_{Clust} = \sum_{i=1}^{n} E_{PV,i} \qquad \text{(eq. 4)}$$

Where:

E_{Clust} = Total energy generated by the cooperative in the first year of operation [kWh/year]

$E_{PV,i}$ = Total energy generation of the BAPV system “i” in the first year of operation [kWh/year]

i = Identification number of the BAPV system [from 1 to n]

n = Number of BAPV systems [20 for the study case]

The installed power of the clustered system is the sum of the installed power of each BAPV unit, as shown in Eq. 5.

$$P_{Clust} = \sum_{i=1}^{n} P_{PVC,i} \qquad \text{(eq. 5)}$$

Where:

P_{Clust} = Clustered installed power [kWp]

$P_{PVC,i}$ = Installed power of the BAPV system “i” [kWp]

i = Identification number of the BAPV system [from 1 to n]

n = Number of BAPV systems [20 for the study case]

With the total clustered values of PV power and energy generated, it is possible to identify the clustered yield (into the cooperative, VPP), as shown in Eq. 6.

$$Y_{Clust} = \frac{E_{Clust}}{P_{Clust}} \qquad \text{(eq. 6)}$$

Where:

Y_{Clust} = Clustered Yield (cooperative, VPP) [kWh/(kWp·year)];

E_{Clust} = Total clustered energy generation [kWh/year]

P_{Clust} = Clustered installed power [kWp]

2.3. Impact analysis

In order to analyze the impact of disturbances in the cooperative caused by the units and compare them with individual performance, the system of greatest influence (Home 6) was used as the basis.

The study uses as a parameter the performance of the group due to energy fluctuations in two scenarios, which present variation of ± 20% in the unit, that is, 120% in an optimistic case and 80% in a pessimistic case.

3. Results

When analyzing the annual PV generation, the results show differences between the two studied situations (clustered or individual), ranging between from -14% to +25% depending on the analyzed BAPV system.

Table 1 shows each BAPV system and its respective generation characteristics. Some cases had results of 25% profit in the annual generation, such as Home 12, which individually had a Yield of 1,061 kWh/(kWp·year), while others had a deficit of 14%, such as the case of Home 20, which had an individual Yield of 1,548 kWh/(kWp·year), before the Yield into the cooperative (1,332 kWh/(kWp·year)).

Table 1: PV Generation and BAPV information of each unit.

Home	Location	Tilt BAPV [Degrees]	Azimuth BAPV [Degrees]	PV power [kWp]	Quota [PV modules]	Share	Credit energy [kWh/year]		Totals of annual average Yield [kWh/(kWp.year)]			Credit Received into the VPP
							Individual	Clustered	Individual [1] Yield BAPV	Clustered [2] Yield VPP	Δ Yield [2] - [1]	
01	Concórdia	35	90	4.00	16	6.1%	4,718	5,328	1,180	1,332	152	12.9%
02	Concórdia	30	0	2.50	10	3.8%	3,855	3,330	1,542	1,332	-210	-13.6%
03	Concórdia	25	0	1.75	7	2.7%	2,672	2,331	1,527	1,332	-195	-12.8%
04	Joaçaba	25	0	2.75	11	4.2%	4,115	3,663	1,496	1,332	-164	-11.0%
05	Palhoça	18	0	2.50	10	3.8%	3,341	3,330	1,336	1,332	-4	-0.3%
06	Chapecó	15	0	7.75	31	11.8%	11,559	10,323	1,491	1,332	-159	-10.7%
07	Quilombo	15	90	2.25	9	3.4%	2,937	2,997	1,306	1,332	26	2.0%
08	Florianópolis	30	0	4.00	16	6.1%	5,649	5,328	1,412	1,332	-80	-5.7%
09	São José	15	0	2.75	11	4.2%	3,633	3,663	1,321	1,332	11	0.8%
10	Curitibanos	30	-90	8.00	32	12.2%	9,160	10,656	1,145	1,332	187	16.3%
11	Florianópolis	25	90	3.50	14	5.3%	3,999	4,662	1,143	1,332	189	16.6%
12	Palhoça	35	90	6.00	24	9.1%	6,369	7,992	1,061	1,332	270	25.5%
13	São José	40	0	3.00	12	4.6%	4,137	3,996	1,379	1,332	-47	-3.4%
14	São José	30	0	2.25	9	3.4%	3,099	2,997	1,377	1,332	-45	-3.3%
15	Florianópolis	35	0	4.00	16	6.1%	5,670	5,328	1,417	1,332	-85	-6.0%
16	Palhoça	35	0	3.25	13	4.9%	4,487	4,329	1,381	1,332	-49	-3.5%
17	Concórdia	17	0	1.00	4	1.5%	1,487	1,332	1,487	1,332	-155	-10.4%
18	Florianópolis	45	0	1.00	4	1.5%	1,406	1,332	1,406	1,332	-74	-5.2%
19	Palma Sola	15	0	2.25	9	3.4%	3,349	2,997	1,489	1,332	-157	-10.5%
20	Concórdia	35	0	1.25	5	1.9%	1,935	1,665	1,548	1,332	-216	-14.0%
Total				**65.75**	**263**	**100%**	**87,576**	**87,576**	**1,332**	**1,332**		

The comparative generation of each system with group generation is identified in Figure 3, which shows some units with clustered generation similar to individual way (Home 05 and 09), others receive more energy from the cooperative than individual generation (Home 01, 07, 10, 11 and 12) and others generate more energy operating individually rather than grouped through the cooperative.

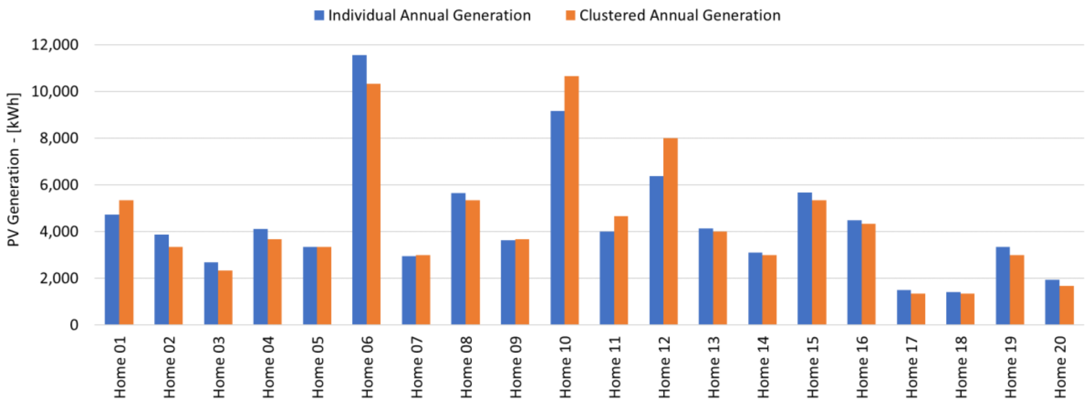


Figure 3: PV annual generation by individual and clustered.

Table 2 shows the same information presented in Table 1, however in an orderly manner, presenting the results from the smallest to the highest individual yield, in order to segment the groups that have more or less benefits.

When analyzing the Azimuth BAPV column, units with 90° of azimuth deviation have lower individual performance, so when joining the cooperative the Yield is improved, causing a significant increase in generation (from 2.0% to 25.5%). The units that do not have azimuth deviation, in turn, contribute to the greater efficiency of the cooperative, since there was a reduction of their clustered generation in relation to the individual.

Table 2: PV Generation and BAPV information of each unit, order by Individual Yield BAPV.

Home	Location	Tilt BAPV [Degrees]	Azimuth BAPV [Degrees]	PV power [kWp]	Quota [PV modules]	Share	Credit energy [kWh/year]		Totals of annual average Yield [kWh/(kWp.year)]			Credit Received into the VPP
							Individual	Clustered	Individual [1] Yield BAPV	Clustered [2] Yield VPP	Δ Yield [2] - [1]	
01	Palhoça	35	90	6.00	24	9.1%	6,369	7,992	1,061	1,332	270	25.5%
02	Florianópolis	25	90	3.50	14	5.3%	3,999	4,662	1,143	1,332	189	16.6%
03	Curitibanos	30	-90	8.00	32	12.2%	9,160	10,656	1,145	1,332	187	16.3%
01	Concórdia	35	90	4.00	16	6.1%	4,718	5,328	1,180	1,332	152	12.9%
02	Quilombo	15	90	2.25	9	3.4%	2,937	2,997	1,306	1,332	26	2.0%
03	São José	15	0	2.75	11	4.2%	3,633	3,663	1,321	1,332	11	0.8%
04	Palhoça	18	0	2.50	10	3.8%	3,341	3,330	1,336	1,332	-4	-0.3%
05	São José	30	0	2.25	9	3.4%	3,099	2,997	1,377	1,332	-45	-3.3%
06	São José	40	0	3.00	12	4.6%	4,137	3,996	1,379	1,332	-47	-3.4%
07	Palhoça	35	0	3.25	13	4.9%	4,487	4,329	1,381	1,332	-49	-3.5%
08	Florianópolis	45	0	1.00	4	1.5%	1,406	1,332	1,406	1,332	-74	-5.2%
09	Florianópolis	30	0	4.00	16	6.1%	5,649	5,328	1,412	1,332	-80	-5.7%
10	Florianópolis	35	0	4.00	16	6.1%	5,670	5,328	1,417	1,332	-85	-6.0%
11	Concórdia	17	0	1.00	4	1.5%	1,487	1,332	1,487	1,332	-155	-10.4%
12	Palma Sola	15	0	2.25	9	3.4%	3,349	2,997	1,489	1,332	-157	-10.5%
13	Chapecó	15	0	7.75	31	11.8%	11,559	10,323	1,491	1,332	-159	-10.7%
14	Joaçaba	25	0	2.75	11	4.2%	4,115	3,663	1,496	1,332	-164	-11.0%
15	Concórdia	25	0	1.75	7	2.7%	2,672	2,331	1,527	1,332	-195	-12.8%
16	Concórdia	30	0	2.50	10	3.8%	3,855	3,330	1,542	1,332	-210	-13.6%
17	Concórdia	35	0	1.25	5	1.9%	1,935	1,665	1,548	1,332	-216	-14.0%
Total				65.75	263	100%	87,576	87,576	1,332	1,332		

Another point to be analyzed is the geographical position of the units. The houses that have 0° of azimuthal angle, are located in the regions with higher solar irradiations (Concordia, Chapecó, Joaçaba, and Palma Sola) and were more impacted by joining the cooperative, obtaining a generation of -10.4% to -14.0% relative to an individual generation. The cities with the lowest irradiation (Palhoça, São José and Florianópolis) had a lower impact with a representation of 0.8% to -6.0% because the difference between their individual Yields and clustered are not so significant.

The interference of each cooperative member has different impacts on the group. For the cooperative, we evaluated the impact of the largest generator into the group, which presented a little disturbance, that is, the system becomes more robust because it reduces the risks involved in the individual annual generation. Home 06 was chosen for having the amount of 31 quota parts (11.8% of the total) and generated 13.2% into the group, which produces the largest amount in the system.

Table 3 shows the influence of each system individually, and the influence of the system with the greatest impact (Home 6) into the cooperative, in three scenarios: (i) Normal Generation; (ii) The influence of generation with 120% and; (iii) The influence with 80% of generation.

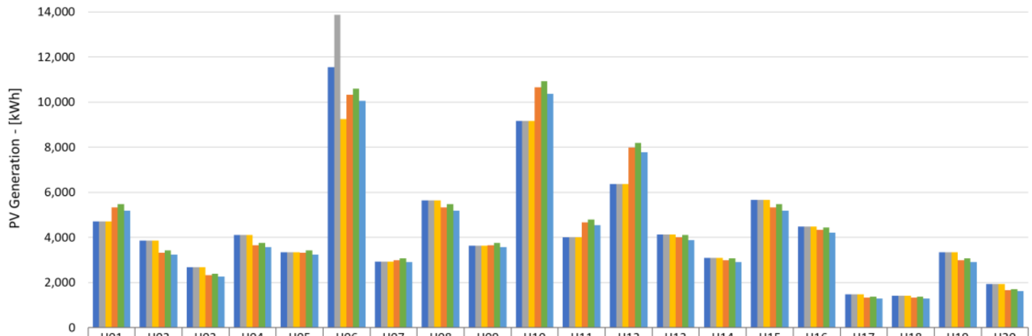
Table 3: PV Generation of and BAPV and Clustered in different cases.

Home	Location	Quota [PV modules]	Share	Credit energy normal case [kWh/year]		Credit energy Home 06 +20% case [kWh/year]		Credit energy Home 06 -20% case [kWh/year]	
				Individual	Clustered	Individual	Clustered	Individual	Clustered
01	Concórdia	16	6.1%	4,718	5,328	4,718	5,468	4,718	5,187
02	Concórdia	10	3.8%	3,855	3,330	3,855	3,418	3,855	3,242
03	Concórdia	7	2.7%	2,672	2,331	2,672	2,392	2,672	2,269
04	Joaçaba	11	4.2%	4,115	3,663	4,115	3,760	4,115	3,566
05	Palhoça	10	3.8%	3,341	3,330	3,341	3,418	3,341	3,242
06	Chapecó	31	11.8%	11,559	10,323	13,870	10,595	9,247	10,050
07	Quilombo	9	3.4%	2,937	2,997	2,937	3,076	2,937	2,918
08	Florianópolis	16	6.1%	5,649	5,328	5,649	5,468	5,649	5,187
09	São José	11	4.2%	3,633	3,663	3,633	3,760	3,633	3,566
10	Curitibanos	32	12.2%	9,160	10,656	9,160	10,937	9,160	10,374
11	Florianópolis	14	5.3%	3,999	4,662	3,999	4,785	3,999	4,539
12	Palhoça	24	9.1%	6,369	7,992	6,369	8,203	6,369	7,781
13	São José	12	4.6%	4,137	3,996	4,137	4,101	4,137	3,890
14	São José	9	3.4%	3,099	2,997	3,099	3,076	3,099	2,918
15	Florianópolis	16	6.1%	5,670	5,328	5,670	5,468	5,670	5,187
16	Palhoça	13	4.9%	4,487	4,329	4,487	4,443	4,487	4,215
17	Concórdia	4	1.5%	1,487	1,332	1,487	1,367	1,487	1,297
18	Florianópolis	4	1.5%	1,406	1,332	1,406	1,367	1,406	1,297
19	Palma Sola	9	3.4%	3,349	2,997	3,349	3,076	3,349	2,918
20	Concórdia	5	1.9%	1,935	1,665	1,935	1,709	1,935	1,621
	Total	**263**	**100%**	**87,576**	**87,576**	**89,888**	**89,888**	**85,264**	**85,264**

It is possible to verify that in scenarios (i) and (ii), the BAPV of Home 6 presents an individual generation larger than clustered way, through the cooperative. In scenario (iii), which has an influence on the generation of-20%, the cooperative begins to become more attractive, because the losses are diluted and compensated with the clustering of more systems.

With the generation fluctuations of scenarios (ii) and (iii), the other units suffered a variation of ±2.64% in generation. The impact portion was distributed among the units, reducing the risk of an individualized unit, thus seeking greater group stability. This stability brings greater robustness to the cooperative and greater safety for generators.

Figure 4 shows that as much as variations are at significant levels for Home 6, their generation will remain at very close levels. And the greater the number of associates, the more sensitive are the variations in generation regarding the share of participation in the cooperative.



	H01	H02	H03	H04	H05	H06	H07	H08	H09	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20
Individual Generation	4,718	3,855	2,672	4,115	3,341	11,559	2,937	5,649	3,633	9,160	3,999	6,369	4,137	3,099	5,670	4,487	1,487	1,406	3,349	1,935
Individual (H06 + 20%)	4,718	3,855	2,672	4,115	3,341	13,870	2,937	5,649	3,633	9,160	3,999	6,369	4,137	3,099	5,670	4,487	1,487	1,406	3,349	1,935
Individual (H06 - 20%)	4,718	3,855	2,672	4,115	3,341	9,247	2,937	5,649	3,633	9,160	3,999	6,369	4,137	3,099	5,670	4,487	1,487	1,406	3,349	1,935
Clustered Generation	5,328	3,330	2,331	3,663	3,330	10,323	2,997	5,328	3,663	10,656	4,662	7,992	3,996	2,997	5,328	4,329	1,332	1,332	2,997	1,665
Clustered (H06 + 20%)	5,468	3,418	2,392	3,760	3,418	10,595	3,076	5,468	3,760	10,937	4,785	8,203	4,101	3,076	5,468	4,443	1,367	1,367	3,076	1,709
Clustered (H06 - 20%)	5,187	3,242	2,269	3,566	3,242	10,050	2,918	5,187	3,566	10,374	4,539	7,781	3,890	2,918	5,187	4,215	1,297	1,297	2,918	1,621

Figure 4: Annual PV energy available for the first year, clustered vs. individual home.

4. Conclusions

This paper demonstrates that the use of a cooperative without any distinction from its members neither previous evaluation about location, useful area, rooftop tilt and orientation, can bring negative influence for cooperative member that are in better conditions and accept to join into the group. Every BAPV systems with Yield lower than the clustered Yield will receive more energy credits joining the cooperative than the energy credits that it would generate by itself. Likewise, every BAPV systems with Yield higher than the group Yield will receive less energy credits joining the cooperative than the energy credits that it would generate by itself.

This paper verified that for a relevant uptake, it is necessary to segment these cooperated systems into equivalent areas, where they have small variation of annual irradiation, or the creation a model of balance and equivalence that takes into account where the cooperative member is located, without significant interference with the system, thus making it more beneficial for all associates.

As can be seen in Table 1, the BAPV systems oriented to the East and West (azimuthal deviation ±90), present significant differences in the Yield, with a 20% reduction in relation to systems oriented to the North (zero azimuth). The Homes 01, 07, 10, 11 and 12 are more benefited when associated into the cooperative (VPP).

As shown in the Table 3, when a system associated has losses in the generation, the clustering system absorb, making this an attractive to a cooperative.

The business model (PV-VPP share), in the case study of this paper, does not prove feasible for cooperatives, because, if the quota participation is defined by the quantity of PV modules, members with individual Yield above the cooperative Yield will have a lower generation share proportional to the quota participation than they would have outside of the cooperative.

5. References

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