Economic feasibility of rainwater harvesting in houses in Blumenau, Brazil

Anthony Midori Fugi, Jéssica Kuntz Maykot, Enedir Ghisi, Liseane Padilha Thives

UNIVERSIDADE FEDERAL
DE SANTA CATARINA

Introduction

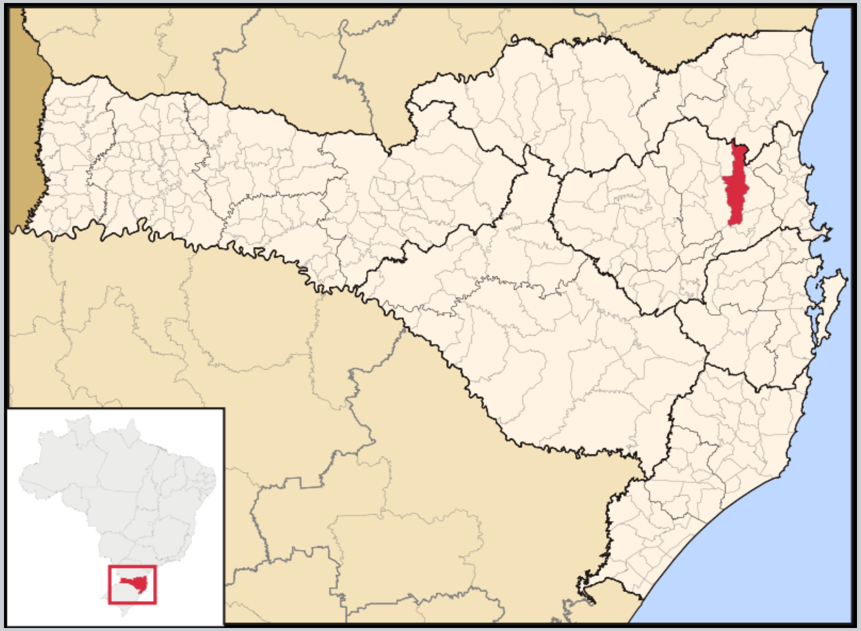
- Storage and rainwater usage bring environmental benefits and may reduce potable water costs;

- economic feasibility analysis must be done on a case-by-case basis, as it depends on several parameters such as: water demand, rainfall, water tariff, costs, roof area, among others;

- Blumenau: Brazilian city which is prone to flooding in certain periods.

Method

- Study area: Blumenau, Southern Brazil;
- Case study performed in a three-storey single-family house
- Roof area of 165 m² and there were 4 people living in the house.



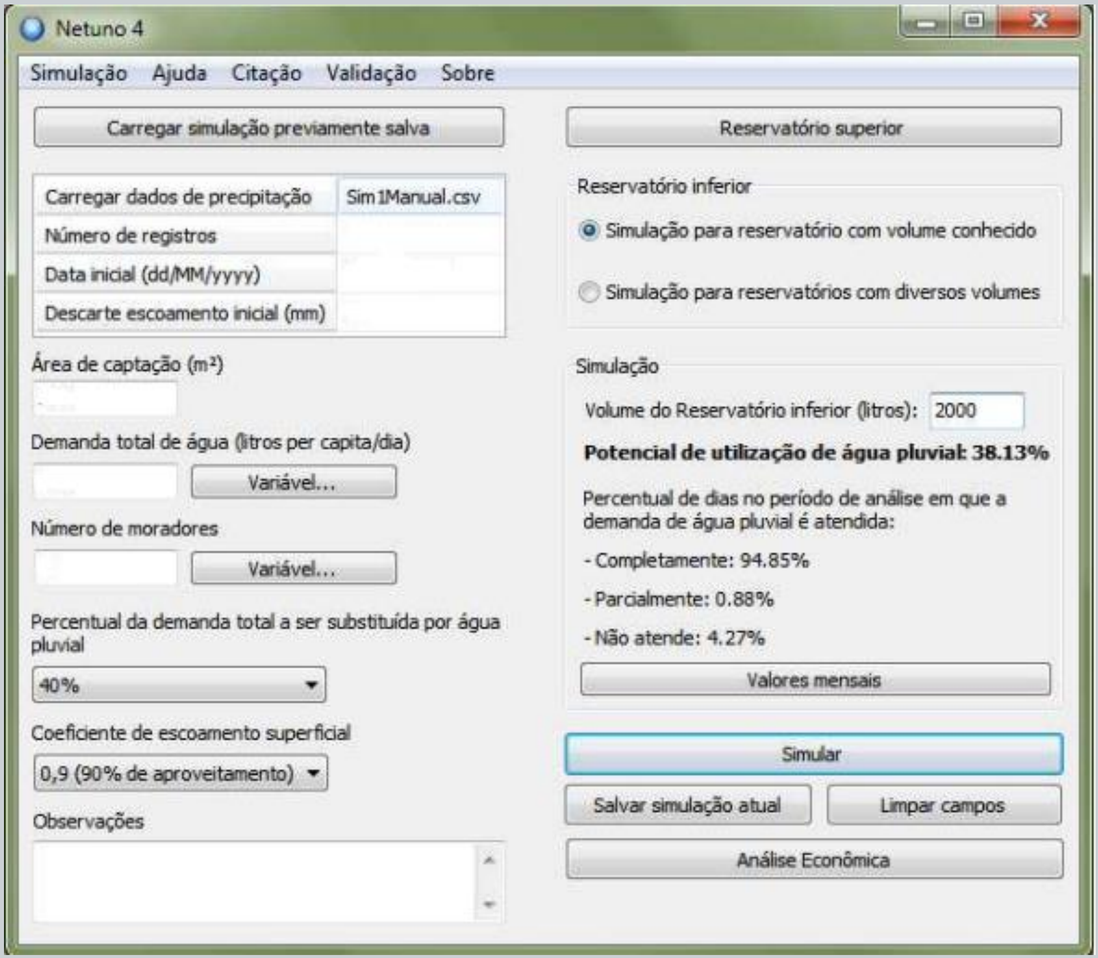
Location of Blumenau in Santa Catarina, Brazil.

Façade of the house.

Method

- Different scenarios of water end-uses were considered;
- Water end-uses and consumption were estimated through questionnaires;
- Residents registered frequency and duration of use of each fixture;
- Water consumption measured in the water meter was recorded for comparison;
- Water flow rates of each fixture were measured using a 500-ml glass and a stopwatch.

Method: Computer simulations



Simulation main window of Netuno version 4.

- *Netuno 4* was used for the sizing of the rainwater storage tank, estimating the potential for potable water savings and performing the economic feasibility analysis

Method: Computer simulations

Input data used in the computer simulations for the actual house.

First flush	2 mm
Roof area	165 m^2
Total water demand	153.2 litres/person/day
Number of residents	4 persons
Rainwater demand	59.3%
Runoff coefficient	0.8

Summary of the parameters tested in the different scenarios.

Parameter	Value
Roof area (m^2)	60 ; 100 ; 140 ; 180
Total water demand (litres/person/day)	100 ; 150 ; 200
Number of residents	2 ; 3 ; 4 ; 5
Rainwater demand (% of total water demand)	30 ; 40 ; 50 ; 60
Lower tank capacity (litres)	500 a 20,000 (at 500-litre interval)
Runoff coefficient	0.8
First flush (mm)	2

Method: Economic Analysis

- Costs of implementing the rainwater harvesting system and the costs of water consumption and system operation were obtained;

- Monetary savings due to the rainwater system were calculated;

- Discounted payback, net present value and internal rate of return were calculated.

- Labour and material costs were obtained from stores and from Brazilian System of Research on Costs and Indices of Civil Construction;

Results: Water consumption and end-uses

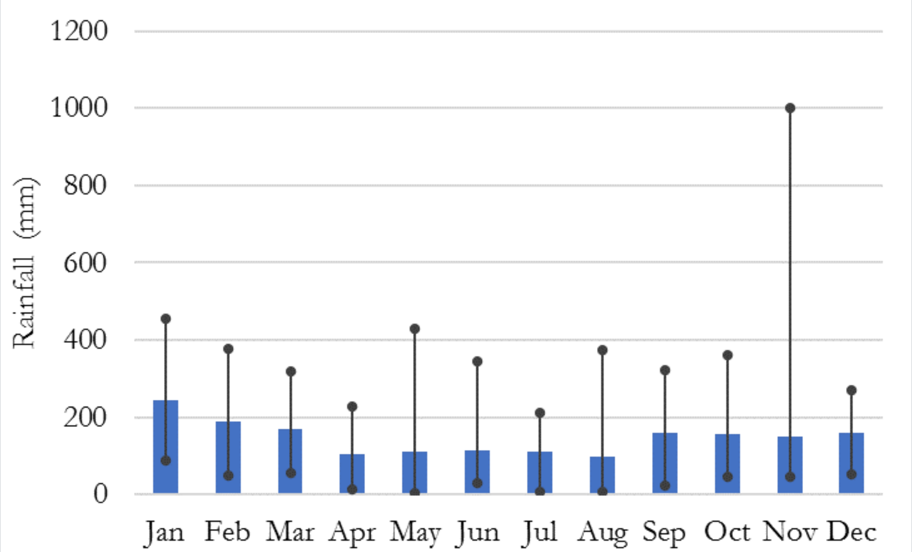
- Average consumption obtained from the water meter: 612.9 litres/day.
- Average monthly consumption: 19.0 m^3
- Average per capita water consumption: 153.2 litres/person/day.

Water Fixture	Water Consumption	
	Litres	%
Showers	985.4	26.8
Washing machine	925.0	25.1
Toilets	777.7	21.1
Kitchen sink	355.9	9.7
Outdoor taps	253.4	6.9
Washing trough	224.1	6.1
Toilet sinks	103.5	2.8
Dishwasher	30.6	0.8
Drinking fountain	23.3	0.6
Total	3678.9	100.0

Water end-uses

Results: Rainwater demand and Rainfall

- Water end-uses for non-potable purposes: 59.3% of the total water demand;
- Rainwater demand for the different scenarios: 30%, 40%, 50% and 60% of the total water demand.



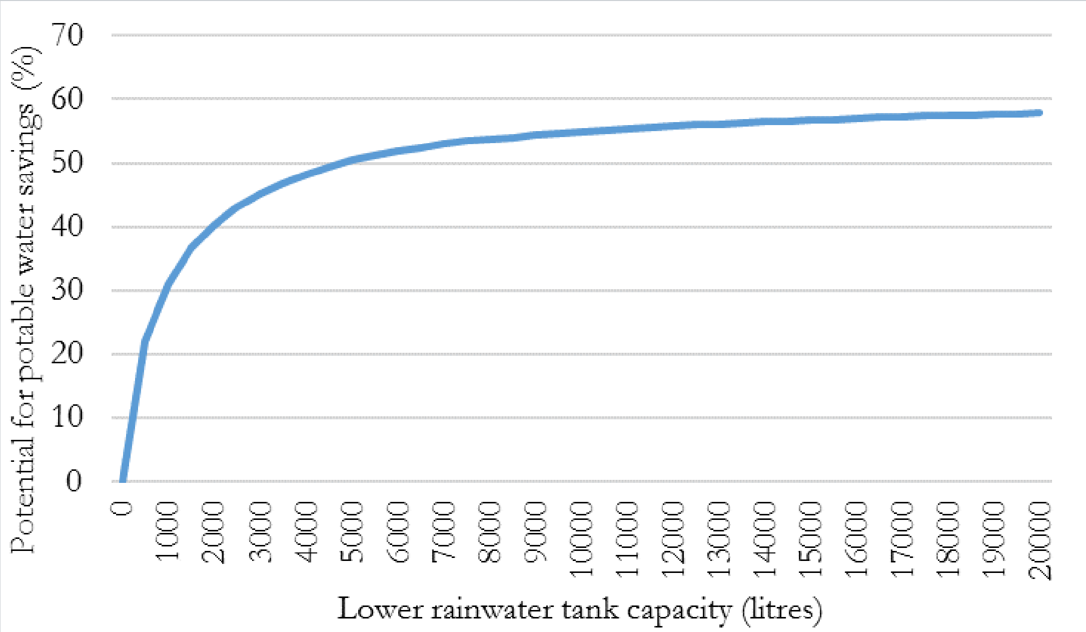
Maximum, minimum and average monthly rainfall for Blumenau over 30 years.

- Daily rainfall data from the Blumenau rain station for the last 30 years (from February 1989 to January 2019).

- Average annual precipitation: 1770 mm.

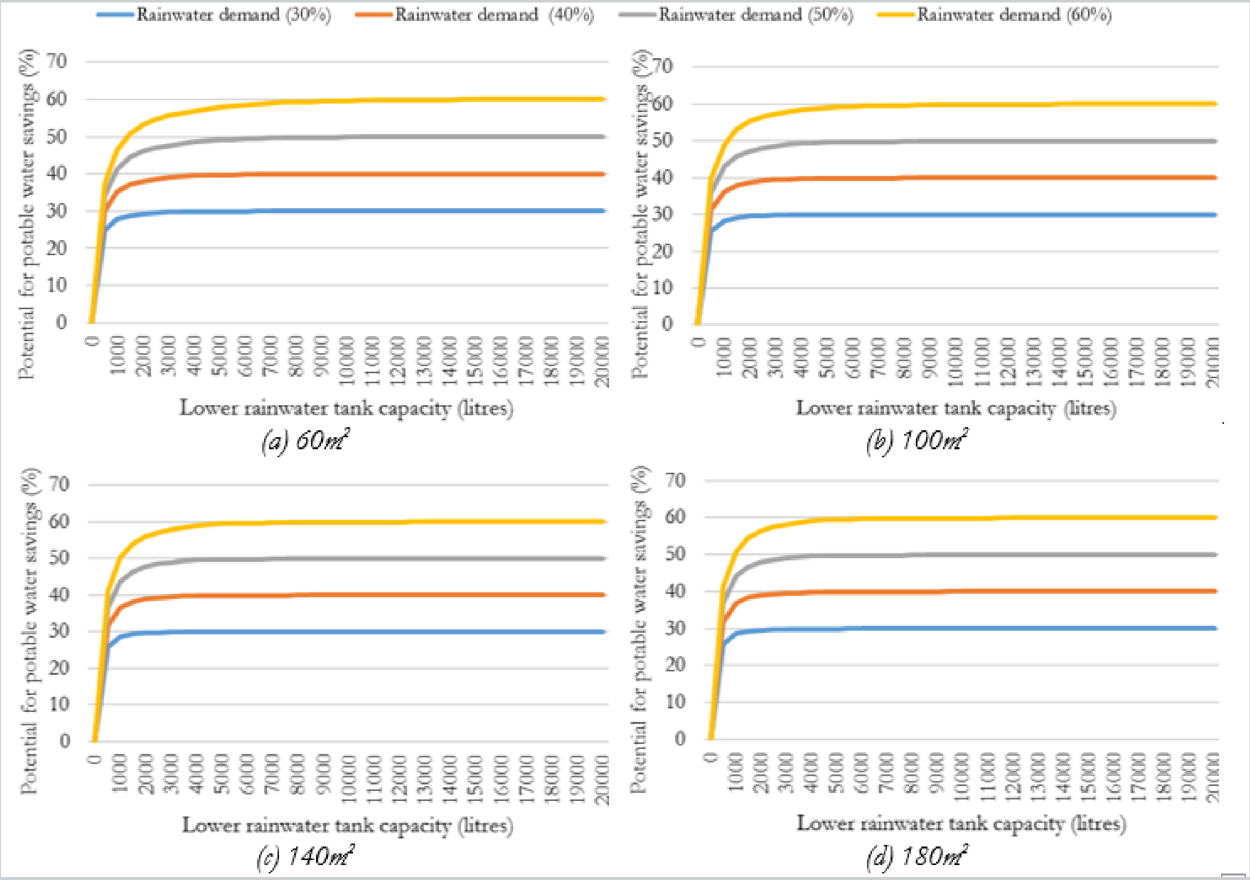
Results: Potential for potable water savings

- For the actual house: the ideal capacity for the lower tank was 5,000 litres and the potential for potable water savings for a 5,000-litre tank was 50.32%.



Potential for potable water savings for the actual house.

Results: Potential for potable water savings



Potential for potable water savings according to each tank capacity (water consumption of 100 litres/person.day, two persons, and four roof areas)

- The potential for potable water savings ranged from 18.76% to 58.06%, with an average of 37.90

- The larger the rainwater demand and roof area, the greater the potential for potable water savings.

Results: Economic Analysis

- For the actual house, a net present value equal to R$ 4814.54, a payback period equal to 89 months and an internal rate of return of 1.44% per month were obtained.

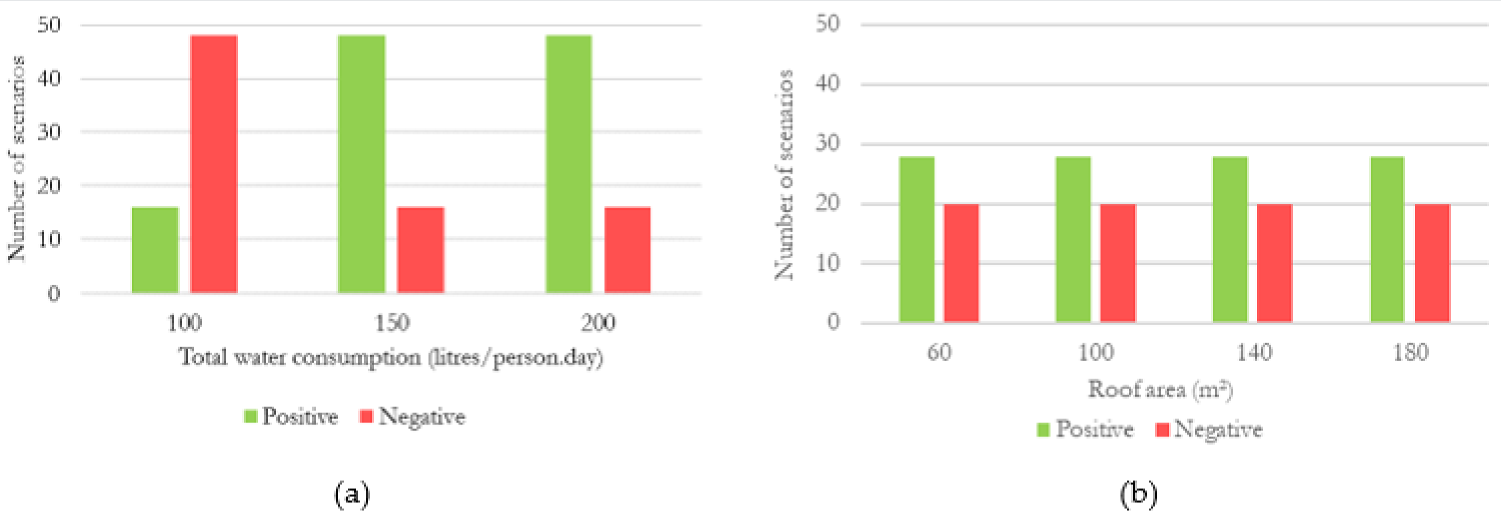
- 112 scenarios (from 192 ones) presented positive NPV, indicating that the rainwater system would be economically feasible for 58.3% of the cases. Payback ranged from 221 to 60 months for economically feasible scenarios and the highest internal rate of return was 2.05% per month.

- Scenarios with low water consumption were economically unfeasible due to the flat rate for monthly consumption of up to 10 m³ of water. Once there is no charge reduction in the water bill, and there is still an expenditure of energy for the operation of the pump, the NPV becomes higher than the initial cost.

Results: Economic Analysis

(a) Water demands of 150 and 200 litres/person/day: NPV was positive for 75% of the cases. Consumptions of 100 litres/person/day: 25% of the cases had positive NPV.

(b) The scenario number does not vary as a function of the roof and the roof area showed no influence on the economic feasibility of rainwater harvesting systems.



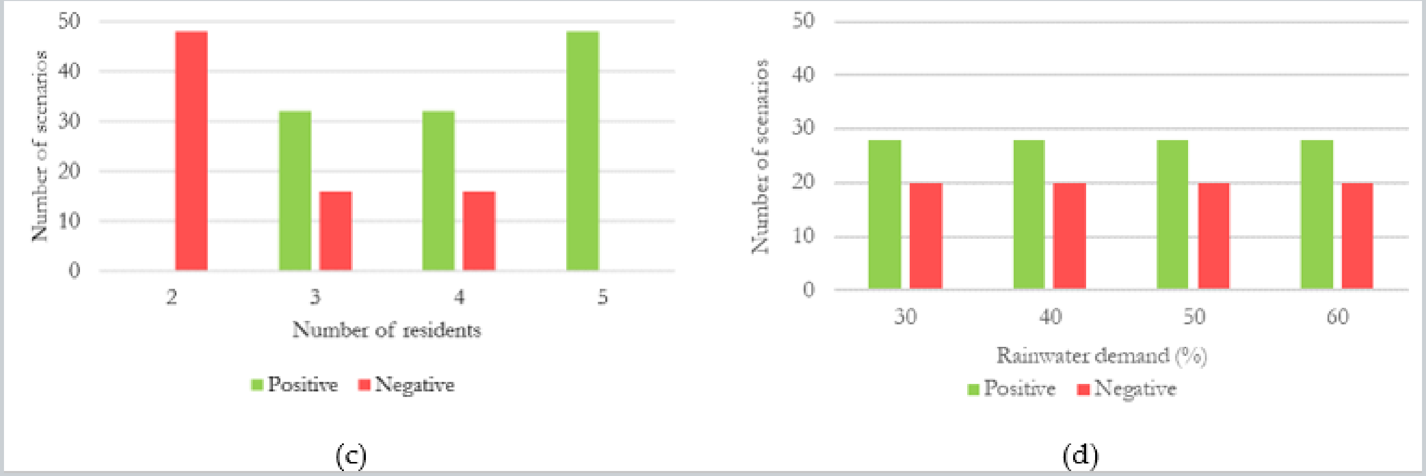
Number of scenarios in which the NPV was positive or negative as a function of the water demand (a) and roof area (b).

Results: Economic Analysis

- The greater the number of residents, the more positive were the NPVs because of water consumptions' increase.

(c) Scenarios with two residents: all NPVs were negative; with five residents: all NPVs were positive. In most scenarios with either three or four residents NPV was positive.

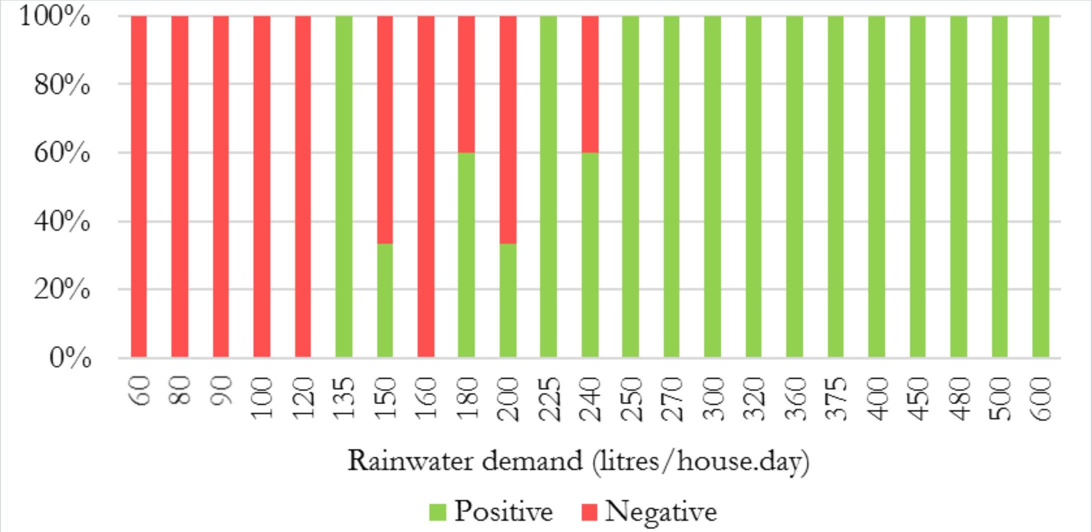
(d) The NPVs were equally distributed for each rainwater demand. For all demands: NPV was positive for 58.3% of the scenarios.



Number of scenarios in which the NPV was positive or negative as a function of number of residents (c) and rainwater demand (d)

Results: Economic Analysis

- Houses with rainwater demand equal to 60–120 litres/day: all scenarios were economically unfeasible.
- When the rainwater demand was greater than or equal to 250 litres/day: all scenarios were economically feasible.
- When the rainwater demand ranged from 135 to 240 litres/day: economic feasibility does not have a trend.



NPV as a function of the rainwater demand for all scenarios.

Conclusions

- This study showed that the higher the water consumption and the higher the rainwater demand, the greater the potential for potable water savings.

- The potential for potable water savings increases as the roof area and the rainwater demand increase.

- In houses with low water consumption, the roof area had little influence on the sizing of the lower rainwater tank.

- For higher consumptions, the tank capacity increased as increases the roof area.

Conclusions

- In houses with high water consumption, the rainwater harvesting system proved to be economically feasible.

- In cases with high rainwater demand and small roof areas, the potential for potable water savings was low, but they were still economically feasible.

- Rainwater harvesting system was not economically feasible for low number of residents and/or low water consumption cases.

- Implementing a rainwater harvesting system for single-family homes in Blumenau is economically feasible for most cases, including the actual house.

Contact

fugianthony@gmail.com

jessica.maykot@posgrad.ufsc.br

enedir.ghisi@ufsc.br

liseane.thives@ufsc.br

UNIVERSIDADE FEDERAL
DE SANTA CATARINA