INTEGRACIÓN EFICIENTE DE
ENERGÍAS RENOVABLES VARIABLES
AL SISTEMA COLOMBIANO

FORECASTING DISTRIBUTED PV ADOPTION IN BARRANQUILLA, COLOMBIA

ASHREETA PRASANNA[1], KATY WAECHTER[1], SEAN ESTERLY[1], KATERIN OSORIO VERA[2]

1. NATIONAL RENEWABLE ENERGY LABORATORY

2. SER (LA ASOCIATIÓN DE ENERGÍAS RENOVABLES COLOMBIA)

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SCOPE OF ANALYSES

The objective of the dGen Colombia project is to provide projections to 2050 on distributed PV deployment by sector for a range of scenarios for Barranquilla, Colombia. NREL used the open-source Distributed Generation Market Demand Model (dGen)[1] (https://www.nrel.gov/analysis/dgen/) adapted for international projects for this analysis. As part of this analysis, technical potential, economic potential, and adoption projections of rooftop and groundmount PV for the city of Barranquilla are presented.

Five main scenarios and their combinations were modeled to provide insight on the impact of increased demand from electric vehicles, air conditioning, and time-of-use tariffs.

PHOTO BY DENNIS SCHROEDER, NREL

dGEN METHODOLOGY AND DATA SOURCES

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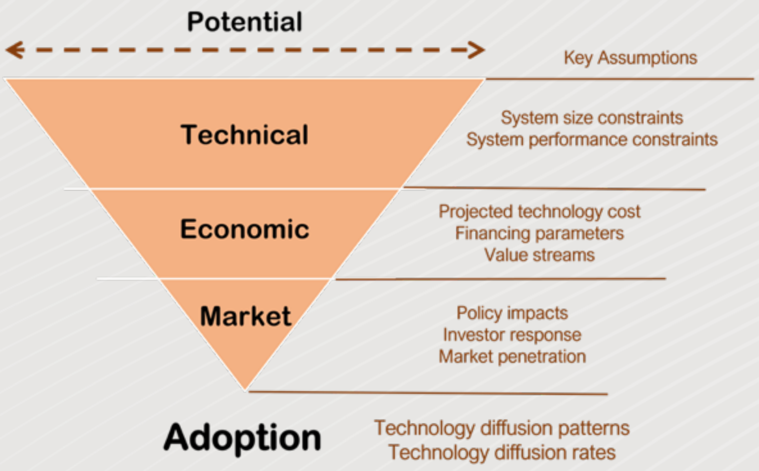
MODELING METHODOLOGY

1. NREL purchased the VRICON 3D Digital Surface Model dataset from Maxar Intelligence Inc. and processed it to obtain roof planes, orientation, and tilt, which was then used to determine the technical potential and generation profiles at building scale for the city of Barranquilla.
2. The technical potential along with other input data were used within the dGen model, which simulates a detailed lifetime cash flow analysis considering resource potential on an hourly basis, hourly load data, retail electricity rates, incentives, and net metering.
3. The dGen model calculates the economic potential, and the bass diffusion framework within the model is used to project adoption over time at high spatial resolution.



dGen Methodology[2]

dGEN COLOMBIA DATA SOURCES

DATA	SOURCE
Utility Rates	Air-e rates for 2021[3]
PV Costs	Unidad de Planeación Minero-Energética (UPME)[4]
Future Utility Rates	NREL Assumptions
Future PV Costs	NREL Assumptions
Base Case Demand Data	SUI, Generation Sole[5]
Scenario Demand Data	Andersen et al.,[6] EVI-Pro Lite,[7] Almedia and Fonseca[8]
Future Demand Growth	Assumptions
Solar Irradiation	NREL NSRDB[9]
Building Data (Roofs)	Processing of VRICON 3D Digital Surface Model data
Historic Deployments	Sistema De Information Electrico Colombiano (SIEL), NREL assumptions
Incentives and Policies	Comisión de Regulación de Energía y Gas (CREG)
Financing Costs	NREL Annual Technology Baseline, World Bank Group

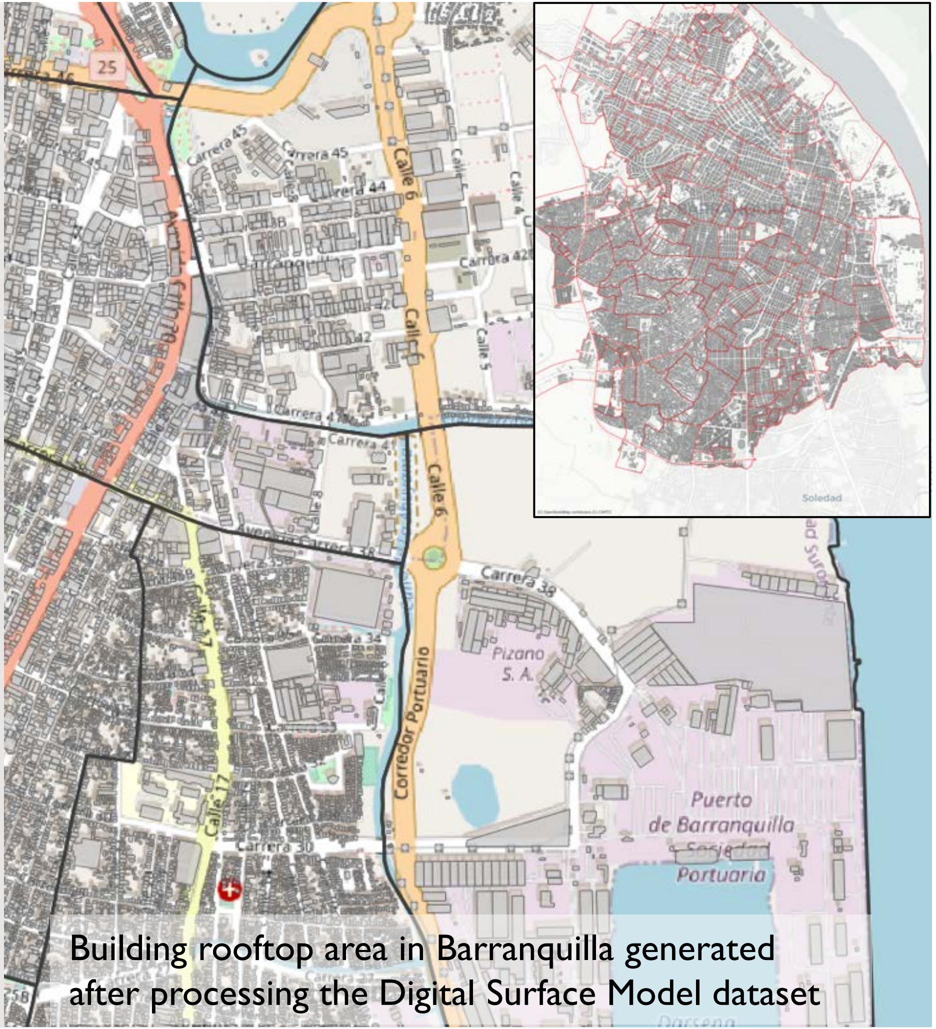
- For each district (189 districts), a representative customer for each sector and estrato was modeled.
- Utility rates are modeled specific to sector (residential, commercial, industrial) and tariff class (estrato 1- 6).
- PV costs considered are specific to system size.

ROOFTOP PV TECHNICAL POTENTIAL

230,297 buildings in 189 districts in Barranquilla are included in the assessment of technical potential for rooftop PV.

From processed data of 3D surface models of buildings, the technical potential for rooftop PV in Barranquilla Colombia is 15.6 GW. The adjusted technical potential accounting for suitability of building structures is 8.4 GW.

SECTOR	NB. BUILDINGS (1000S)	TECHNICAL POTENTIAL (GW)
Residential	191	6.8
Commercial	35	3.7
Industrial	4	5.2
Total	230	15.6



Building rooftop area in Barranquilla generated after processing the Digital Surface Model dataset

SUITABILITY OF BUILDINGS FOR ROOFTOP SOLAR

The suitability of building structures and rooftops for solar installations in Colombia is described in a report from UNEP and Generation Sole.[5] Based on this data, the technical potential for rooftop solar on buildings in Barranquilla is adjusted to 8.4 GW, as shown in the table below.

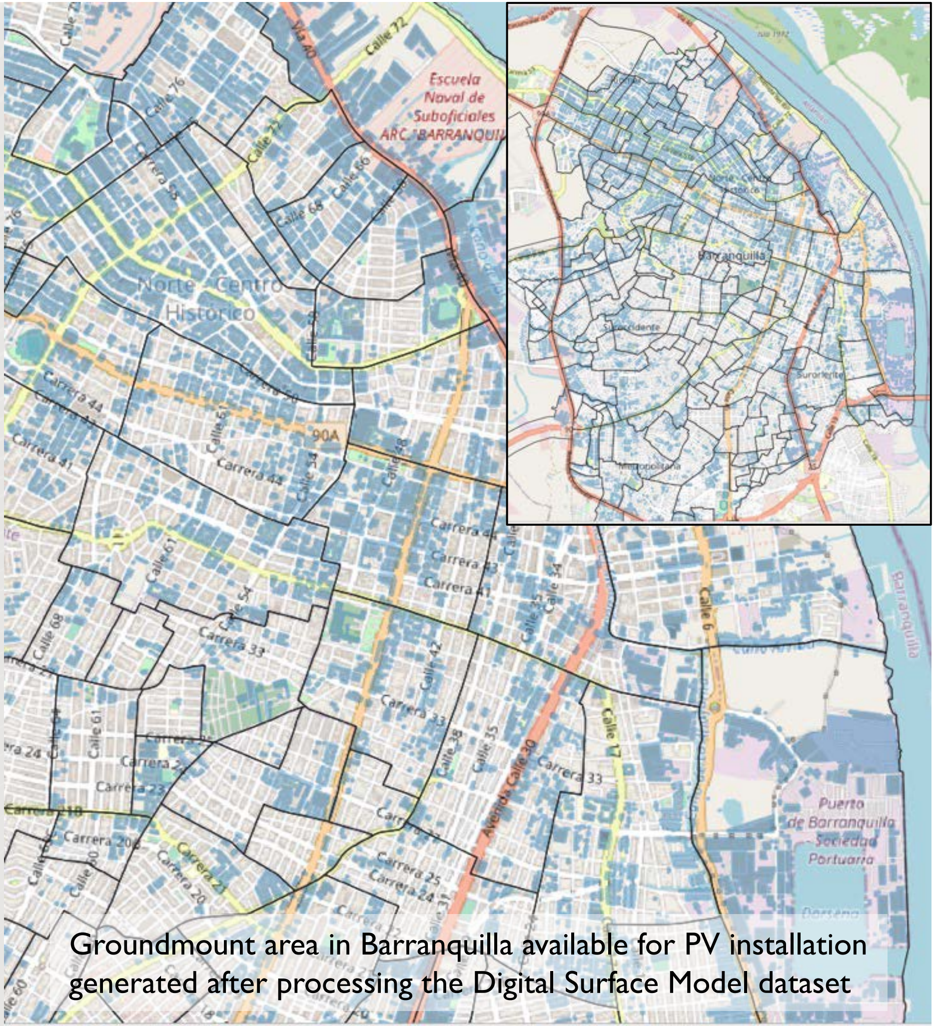
SECTOR	NB. BUILDINGS (1000S)	TECHNICAL POTENTIAL (GW)	PERCENTAGE OF SUITABLE BUILDINGS	ADJUSTED TECHNICAL POTENTIAL (GW)
Residential buildings Strata 1- 3	168	4.4	58%	2.3
Residential buildings Strata 4 - 6	24	2.4	66%	1.6
Commercial buildings	35	3.7	50%	1.9
Industrial buildings	4	5.2	50%	2.6
Total	**230**	**15.6**		**8.4**

GROUNDMOUNT PV TECHNICAL POTENTIAL

33,408 properties in189 districts in Barranquilla were found to have groundmount PV technical potential.

The total technical potential for groundmount PV in Barranquilla, Colombia, is 485 MW.

SECTOR	NB. BUILDINGS (1000S)	TECHNICAL POTENTIAL (MW)
Residential	22	201
Commercial	8	80
Industrial	2	204
Total	**32**	**485**

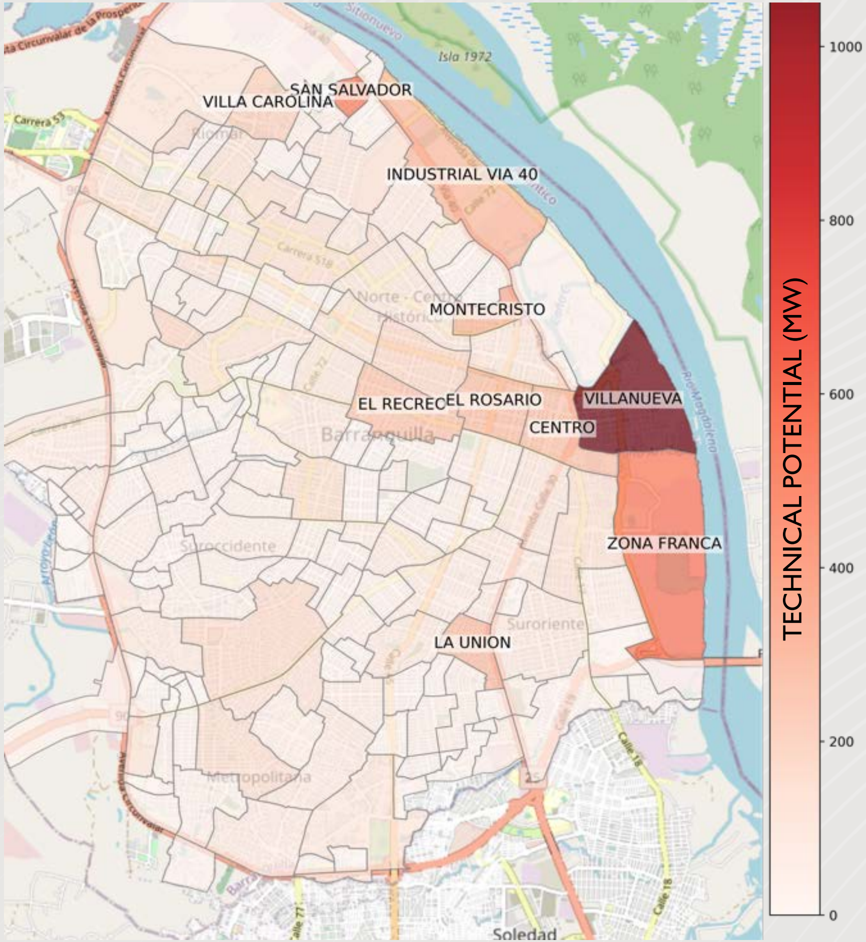


Groundmount area in Barranquilla available for PV installation generated after processing the Digital Surface Model dataset

TECHNICAL POTENTIAL BY DISTRICT

The top ten districts with the highest rooftop PV technical potential in Barranquilla are listed in the table below.

DISTRICT NAME	TECHNICAL POTENTIAL (MW)
VILLANUEVA	1,135
ZONA FRANCA	515
SAN SALVADOR	512
MONTECRISTO	314
INDUSTRIAL VIA 40	285
LA UNION	277
EL ROSARIO	270
CENTRO	262
EL RECREO	245
VILLA CAROLINA	206



RESULTS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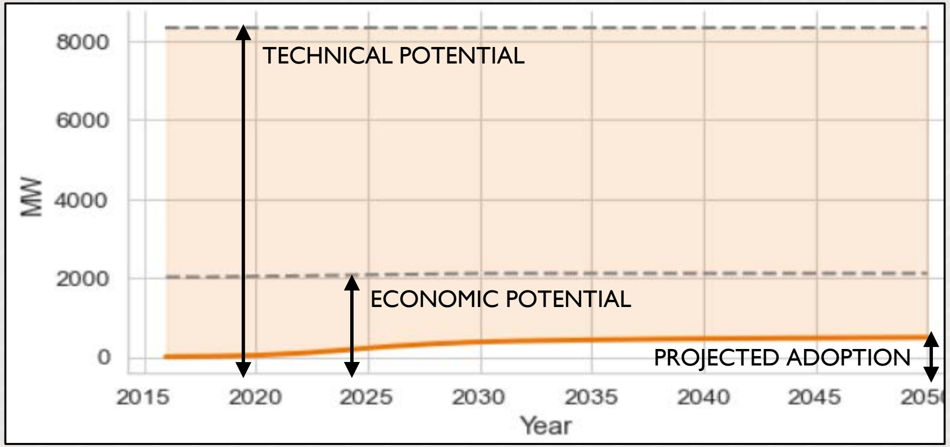
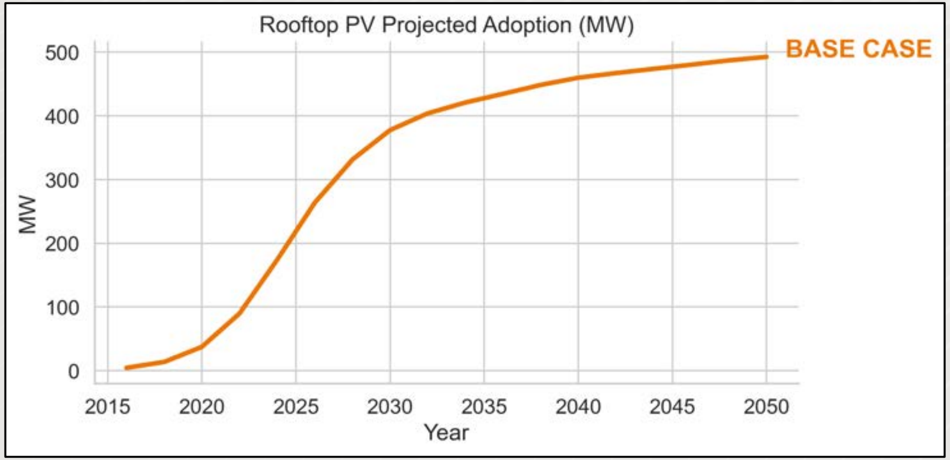
RESULTS BY SCENARIO

The economic potential (total capacity with positive net present value) in Barranquilla is 2,115 MW.

Of this, 493 MW of rooftop solar capacity is projected to be adopted by 2050 in the Base Case scenario.





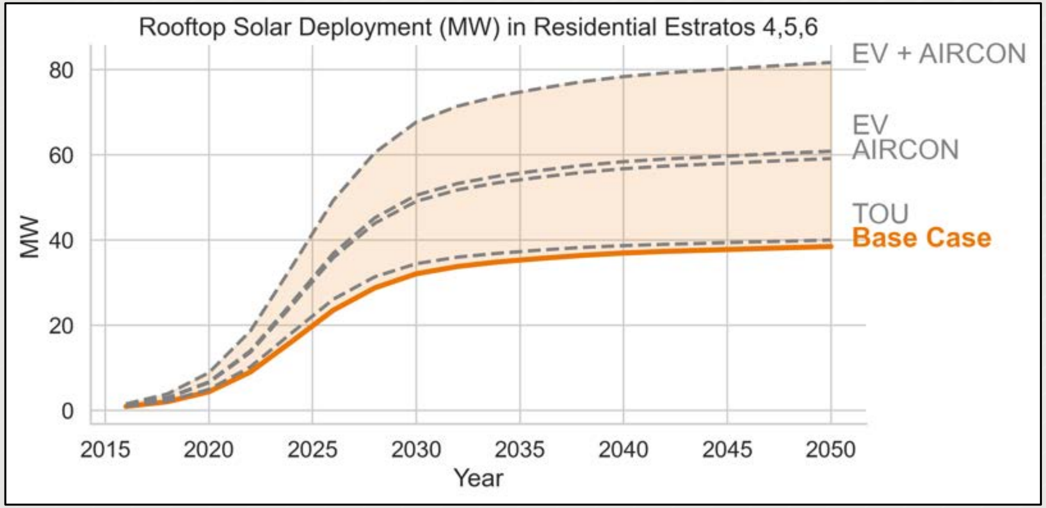
RESULTS BY SCENARIO

Six scenarios and their combinations were modeled to provide insight on the impact of increased demand from electric vehicles, air conditioning, and time-of-use tariffs.

SCENARIOS	ABBREVIATED NAME	DESCRIPTION
Base Case	BASE CASE	Considers current policy and regulatory framework, which includes net-energy metering and tax incentives on PV cost. Only adoption of rooftop PV is evaluated.
Time-of-Use Tariffs	TOU	Considers current policy and regulatory framework, along with a time-of-use tariff, which is applied additionally for the residential sector Estratos 4, 5, and 6.
Electric Vehicle Adoption	EV	Considers current policy and regulatory framework, along with electric vehicle adoption by the residential sector Estratos 4, 5, and 6. The annual consumption of these these specific estratos increases accordingly.
Air Conditioning Adoption	AIRCON	Considers current policy and regulatory framework, along with air-conditioning adoption by the the residential sector Estratos 4, 5, and 6. The annual consumption of these specific estratos increases accordingly.
Electric Vehicle and Air Conditioning Adoption	EV + AIRCON	Considers current policy and regulatory framework, along with both electric vehicle and air-conditioning adoption by the the residential sector Estratos 4, 5, and 6. The annual consumption of these specific estratos increases accordingly.
Groundmount PV Adoption	GM PV	Considers current policy and regulatory framework, which includes net-energy metering and tax incentives on PV cost; however, only adoption of groundmount PV is evaluated.

RESULTS BY SCENARIO

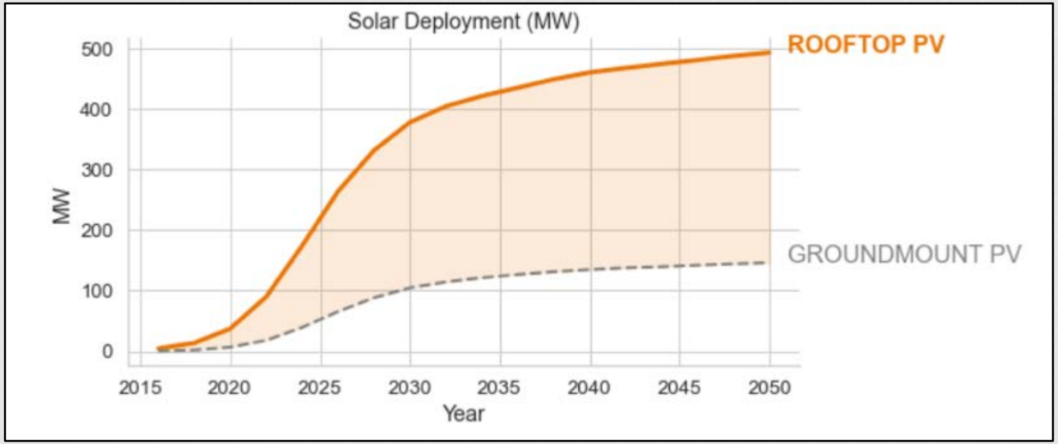
The projected rooftop solar capacity in Barranquilla by 2050 increases to 536 MW when considering the impact of both air conditioning and EV adoption in the residential estratos.



SCENARIO	TOTAL ROOFTOP PV (MW) IN 2050
EV + AIRCON	536
EV	515
AIRCON	513
TOU	494
BASE CASE	493

*The results by scenario are shown only for the residential Estratos 4, 5, and 6 because time-of-use tariffs and changes in annual demand due to EV and air conditioning adoption are applied only for these specific estratos.

RESULTS BY SCENARIO



SCENARIO	TECHNICAL POTENTIAL (MW)	PROJECTED ADOPTION (MW) IN 2050
ROOFTOP PV (BASE CASE)	8,400	493
GROUNDMOUNT PV	485	146
TOTAL	8,885	639

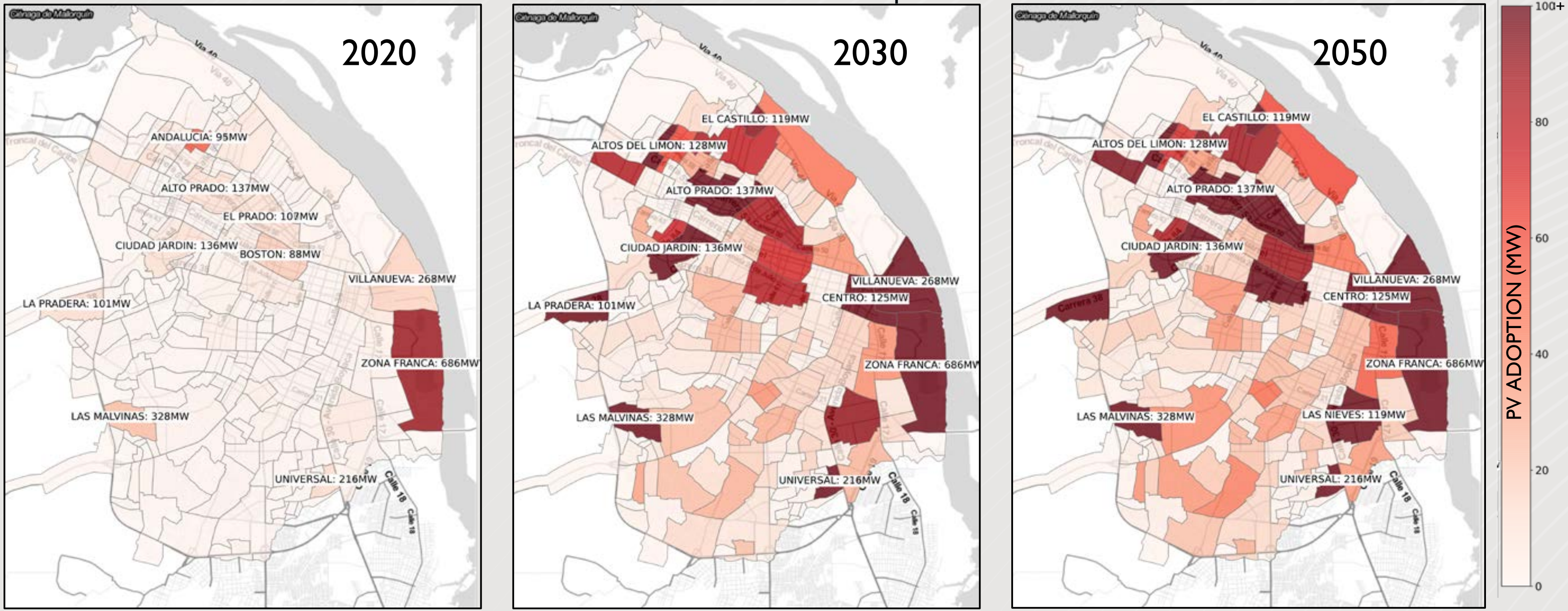
The projected adoption of both rooftop and groundmount solar capacity in Barranquilla by 2050 is 639 MW.

A higher percentage of the developable groundmount solar is adopted because most of the technical potential is found on commercial and industrial properties where payback periods drop to below 5 years by 2030.

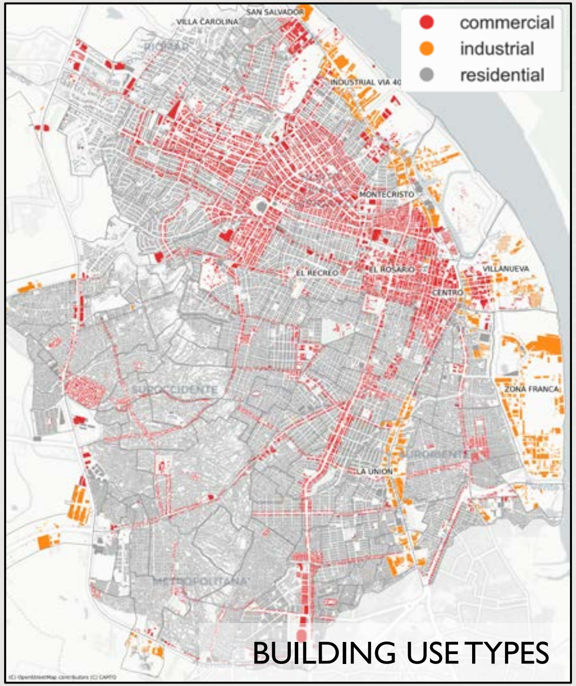
Note that the maximum installable capacity of rooftop PV is capped at the maximum demand of the customer, while the maximum installable capacity for groundmount PV is capped at the specified interconnection limits by sector in Colombia.

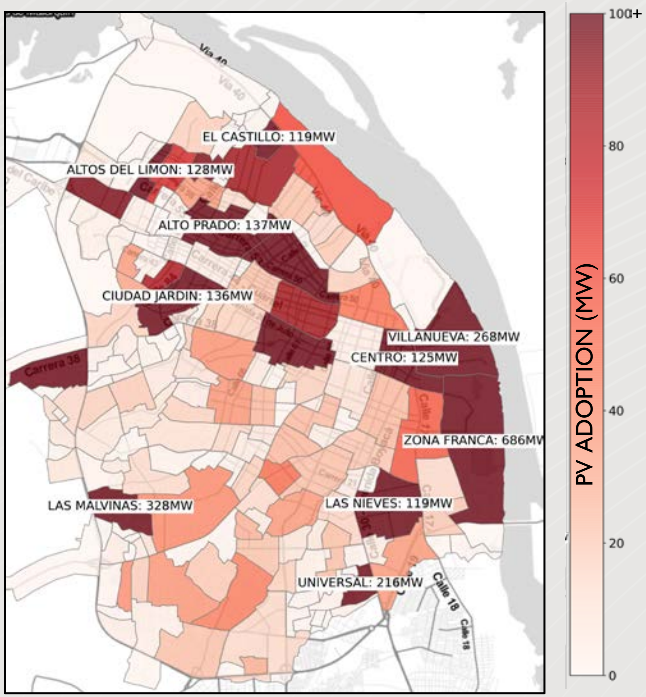
RESULTS BY DISTRICT

The figures below show the projected rooftop PV adoption over time in the districts of Barranquilla. Darker shares of red indicate higher adoption, and the top ten districts with the highest adoption are indicated on the maps.



RESULTS BY DISTRICT

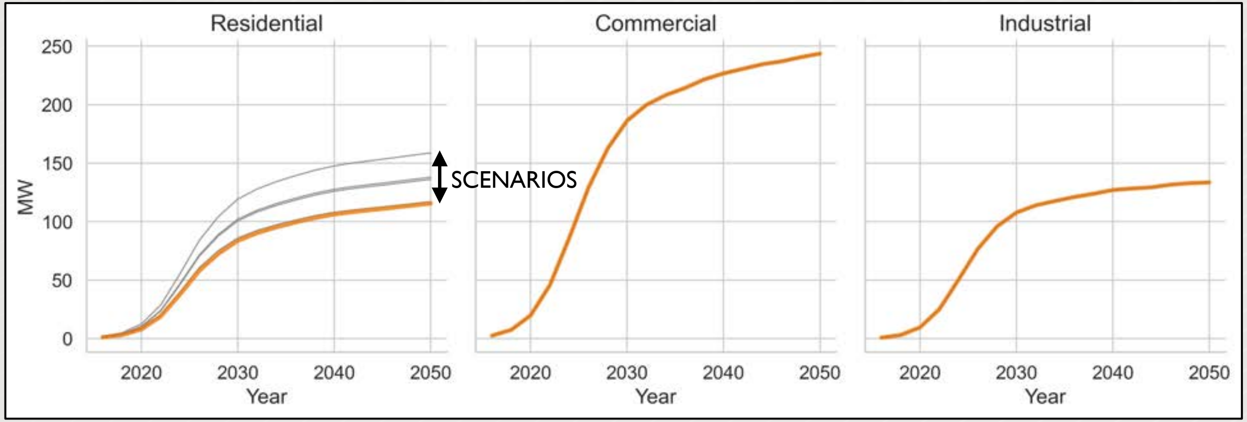




Districts with higher projected rooftop solar adoption tend to have more commercial and industrial buildings, highlighting the economic value of installing rooftop and groundmount PV for these sectors.

In the figure on the left, buildings in red and orange are identified to have commercial and industrial use. In the figure on the right, we see districts with higher percentage of these building types tend to have higher PV adoption.

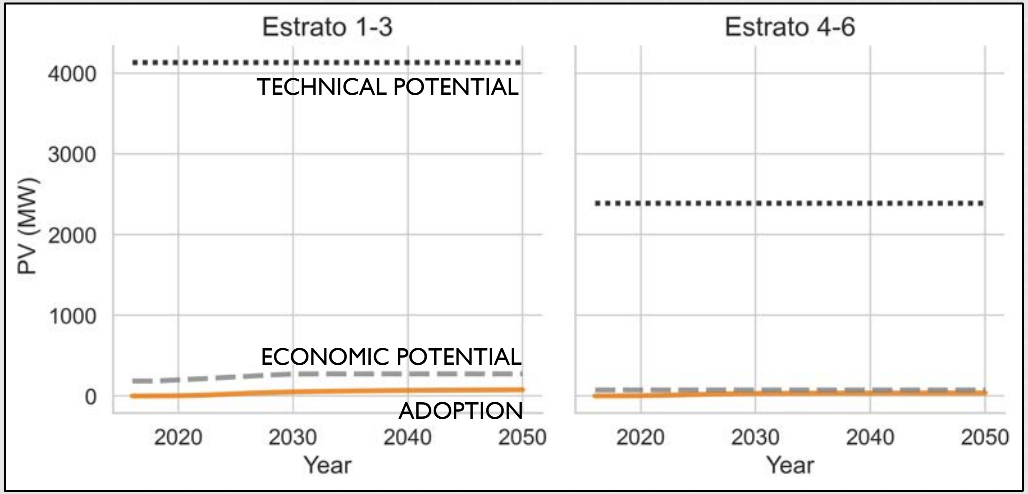
RESULTS BY SECTOR

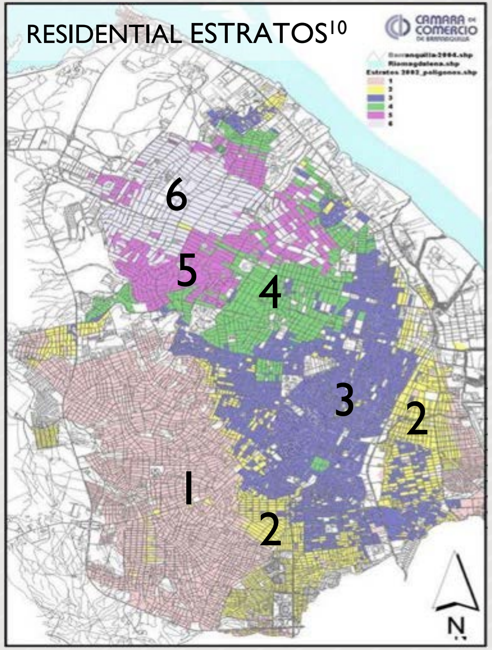


The commercial sector has both the highest economic potential (total capacity with positive net present value) and highest projected adoption of PV, with 244 MW of rooftop PV and an additional 24 MW of groundmount PV by 2050.

SECTOR	ECONOMIC POTENTIAL (MW)	ROOFTOP PV (MW) 2050	GROUNDMOUNT PV (MW) 2050
Residential	2,913	115	70
Commercial	5,911	244	24
Industrial	1,923	133	52

RESULTS BY RESIDENTIAL TARIFF CLASS



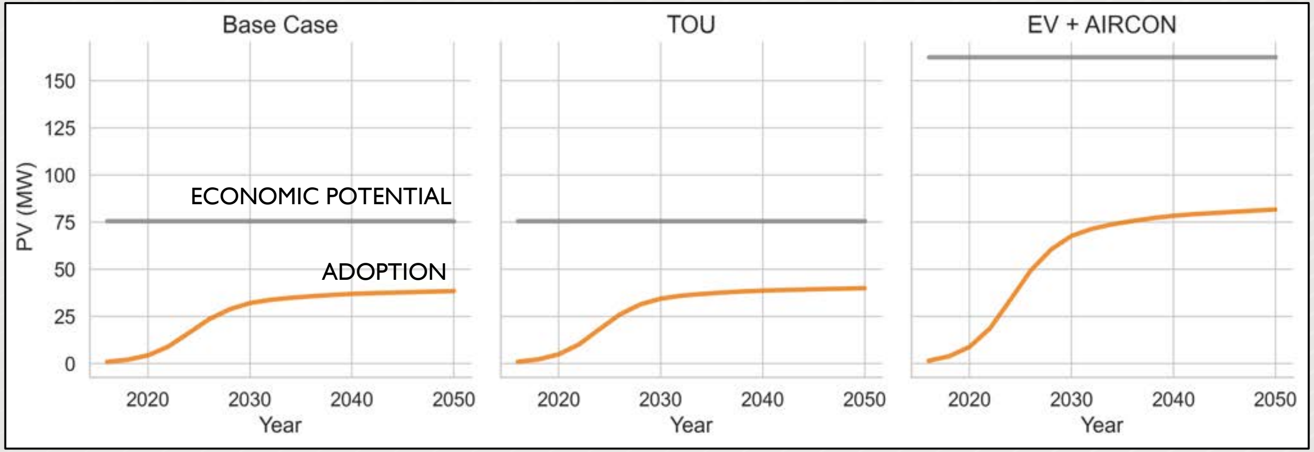


From the figure above, the residential tariff classes Estratos 1, 2, and 3 have higher technical potential and economic potential compared to Estratos 4, 5, and 6.

However, model projections show that a higher proportion of economic systems in Estratos 4, 5, and 6 are adopted by 2050 compared to Estratos 1, 2, and 3. This is primarily due to longer payback periods for rooftop PV for these tariff classes.

TARIFF CLASS	TECHNICAL POTENTIAL (MW)	ECONOMIC POTENTIAL (MW)	ADOPTION (MW)
Estrato 1-3	4,135	274	77
Estrato 4-6	2,392	76	38

RESULTS BY RESIDENTIAL TARIFF CLASS

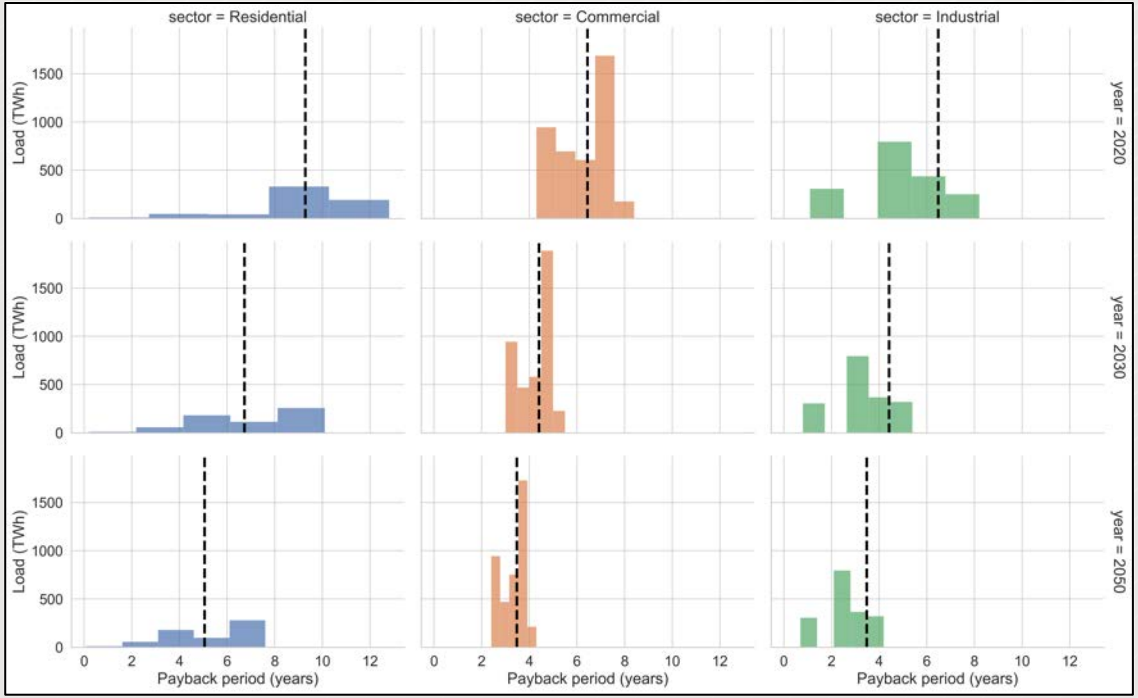


From the figure above, the economic potential and adoption for Estratos 4, 5, 6 under the Base Case scenario, the Time-of-Use scenario, and the Electric Vehicle and Air Conditioning Adoption scenario are compared.

The economic potential does not increase in the Time-of-Use scenario, but adoption increases slightly compared to the Base Case scenario (increase of 1.5 MW), reflecting a decrease in payback periods for PV systems.

Under the Electric Vehicle and Air Conditioning Adoption scenario, both the economic potential and adoption increase compared to the Base Case scenario, with an increase of 86 MW of economic potential and 43 MW of adoption. Therefore, electric vehicle and air conditioning adoption in tariff classes Estratos 4, 5, and 6 will lead to an increase of rooftop PV adoption, given the scenario assumptions.

RESULTS



The figure to the left shows the payback periods by year and sector for the Base Case scenario.

The average payback period of the residential sector decreases from 9 years to 5 years by 2050 due to reductions in PV costs. Similarly, the average payback for the commercial and industrial sectors reduce from 6 years to 3 years by 2050.

RESULTS

SECTOR	ANNUAL LOAD (TWH)	ANNUAL GENERATION FROM ROOFTOP PV IN 2030 (TWH)	ANNUAL GENERATION FROM ROOFTOP PV IN 2030 (%)
Residential	0.64	0.82	128%
Commercial	4.24	1.37	32%
Industrial	1.84	0.25	14%
Total	**6.25**	**2.44**	**36%**

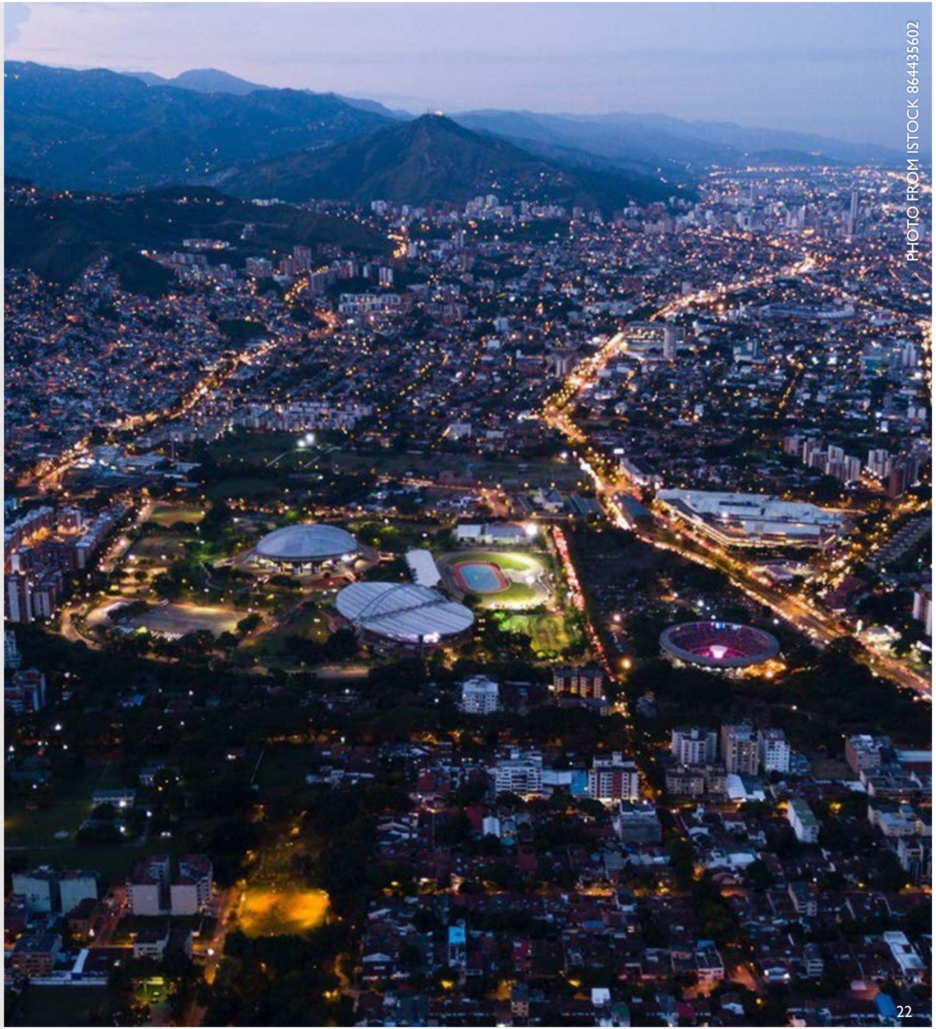
Barranquilla could meet **36%** of its annual demand through rooftop PV by 2030. However, there is an excess of generation compared to consumption in the residential sector, so the excess generation would have to be utilized across all sectors.

SECTOR	TECHNICAL POTENTIAL (GW)	NB. BUILDINGS (1000S)	BUILDINGS WITH PV IN 2020	BUILDINGS WITH PV IN 2030	BUILDINGS WITH PV IN 2050
Residential	3.9	191	2%	24%	33%
Commercial	1.9	35	1%	14%	19%
Industrial	2.6	4	1%	15%	19%
Total	**8.4**	**230**	**2%**	**22%**	**31%**

22% of buildings in Barranquilla are projected to have rooftop solar by 2030 and **31%** of buildings by 2050.

SUMMARY

- The technical potential for rooftop PV in Barranquilla is significant and equals 8.4 GW after accounting for suitability of buildings to install rooftop PV. The technical potential for groundmount PV is 0.45 GW.
- Most of the economic potential (total capacity, which has a positive net present value) is in the commercial and industrial sector; however, the residential sector has the higher technical potential compared to the other sectors.
- Increased consumption from electric vehicle and air conditioning adoption in the tariff classes Estratos 4, 5, and 6 are expected to drive an increase in rooftop PV adoption. Time-of-use tariffs applied to these tariff classes also drive adoption, but the increase is more modest.



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THANK YOU
ASHREETA PRASANNA
(Ashreeta.Prasanna@nrel.gov)
NATIONAL RENEWABLE
ENERGY LABORATORY
NREL/PR-7A40-83572
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