Puerto Rico Demand Response Impact and Forecast Tool (PR-DRIFT) – *beta version*

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Background
**Demand Response (DR):** “changes in utility-supplied electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity during a day and/or season, or to other economic compensation designed to induce change in the use of utility-supplied electricity, to provide a resource option for electric system planners and operators in balancing supply and demand.” (Puerto Rico Energy Bureau Definition in [DR Regulation](#))

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**Peak Shaving**
DR can reduce peak load or net peak load in grids w/ high variable renewable energy (VRE) penetration by curtailing certain end- uses. This could reduce the required generation capacity that needs to be built.

**Flexible Loads**
DR can shift flexible loads from peak to off-peak hours to better align demand with supply. This could reduce VRE curtailment and the ramping requirements of thermal generators.

**Emergency Shedding**
DR can enable targeted load shedding when grid is highly stressed (e.g., large industrial customers shift to backup generation during contingency events like severe weather or unplanned generator outages).

**End-Uses**
The following end-uses can be involved in DR programs: smart appliances, water heaters, residential/commercial thermostats, air conditioning, pool pumps, behind-the-meter generation w/ storage, electric vehicles (EVs), etc.

**Programs**
Participants in a DR program receive payments from utilities or DR aggregators when electricity consumption is curtailed or respond to time-of-use pricing to shift consumption to lower-cost periods.
Demand Response Applications & Considerations

Electricity Grid Challenges and Severe Weather

- DR contributes to system resiliency and reliability by giving system operators more flexibility to match demand with supply on a regular basis and conduct more targeted load shedding on an emergency basis.

100% Renewable Electricity Goal

“Puerto Rico Energy Public Policy Act”

Act No. 17 of April 11, 2019

term. For such purpose, a Renewable Portfolio Standard is established in order to achieve a minimum of forty percent (40%) on or before 2025; sixty percent (60%) on or before 2040; and one hundred percent (100%) on or before 2050.

- DR increases load flexibility and helps grid operators more efficiently match the supply of VRE (e.g., solar PV and wind turbines) to demand at each hour of the day in order to achieve Puerto Rico’s 100% RPS goal by 2050.

Motivation for Demand Response in Puerto Rico

High Fossil Fuel Imports

- DR reduces peak generation needs and can shift load to times of high VRE generation. This decreases Puerto Rico’s reliance on fuel imports and accelerates the retirement of fossil-fuel peaker plants to meet PR goals.

High Electricity Rates

- DR reduces customer electricity consumption and/or shifts consumption to times of lower rates, resulting in lower electricity costs. DR programs can also have financial incentives for participating ratepayers.

Source: Axios, Yacob Reyes, October 3 2021
Prior Applications of Demand Response in Puerto Rico

Puerto Rico Electric Power Authority (PREPA) 2019 Integrated Resource Plan (IRP):

• Sets a goal to acquire 60 MW of DR by 2025 & 82 MW by 2038.
• Evaluates residential DR potential: load control of air-conditioning.
• Evaluates commercial DR potential: load control of air-conditioning and lighting.
• Excludes other end-uses & large commercial/industrial customers from DR program consideration.

PREB Final Resolution & Order on PREPA 2019 IRP:

• Some commercial & industrial customers have used backup generation during emergencies of inadequate centralized generation (e.g, January 2020 earthquake damage to Costa Sur plant) to maintain power quality and reliability by effectively reducing PREPA’s net peak load.
• Estimated 200 MW of backup diesel generation may be currently available from industrial customers.
PREB Regulations for Demand Response

PREB Final Resolution & Order on PREPA 2019 IRP:

• PREPA must develop a demand response resource projection for the next IRP and account for distributed storage resources as demand resources, part of a virtual power plant, or both.

• PREPA must promptly develop programmatic costs informed by engaging commercial and industrial customers and investigate interruptible load tariffs for these customers.

• PREPA must investigate the potential for commercial and industrial self-generation during emergencies.

PREB Regulation for Demand Response:

• PREPA must consider all cost-effective DR measures (technological and rate-based) and perform analysis of whether DR programs could replace generation or other grid investments.

• Fossil-fuel backup generators may participate in DR programs that call for dispatch only in power supply or grid contingency situations in which customers would lose electric service without the resources.

• PREPA must consider DR programs that include different technologies and dispatch with different frequencies, including those which might dispatch daily (ex. energy storage), occasionally (a few times per year), and only in emergency situations.
PR-DRIIFT Features

PR-DRIIFT is a spreadsheet-based tool in which users can estimate the potential impacts to the load profile of demand response, energy efficiency, and variable renewable energy (VRE) and storage adoption in Puerto Rico from 2021 through 2040.
PR-DRIFT builds off the previously developed Puerto Rico Energy Efficiency Scenario Analysis Tool (PREESAT).

**Goal:** A user-customizable spreadsheet tool to roughly estimate the impact to the load profile of DR in Puerto Rico across sectors.

**Audience:** PREPA/LUMA & PREB (for developing DR resource projection) + other key stakeholders (ex. DR aggregators, researchers).
Baseline Load Curves: Net Load & Variable Renewable Energy (VRE)

Baseline business as usual (BAU) 8760 load profiles were developed for the residential, commercial, and industrial sectors from FY21 – FY40, based on PREPA-provided data from FY16 and scaled according to the IRP projections. (Detailed assumptions on the “Baseline_Gross Demand-8760” and “Forecast_Gross Demand-8760” tabs)

Solar PV adoption is phased in according to the mandated procurement schedule in “PREB Resolution on PREPA 2019 IRP” and the RPS of 60% VRE generation by 2040 in “P.L.17-2019”, in order to create a baseline net load profile. The PV load profile is modeled via PVWatts, and the wind turbine load profile is modeled via SAM. (Detailed assumptions on the “Forecast_VRE Built-Annual” and “Forecast_Net Gross Demand-8760” tabs)
Energy Efficiency (EE)  
(Detailed assumptions on the “User Input_EE Measures” tab)

- EE can be turned ON or OFF from the “User Input_Main Dashboard” tab.
- User inputs for energy efficiency can be taken directly from PREESAT results if desired.
- EE impacts are incorporated into the baseline load profiles if EE is turned ON.

Storage  
(Detailed assumptions on the “Forecast_Storage Built-Annual” and “Forecast_Storage Charge-8760” tabs)

- Batteries are sized in FY40 to absorb maximum curtailed VRE in a 4-hour period of the year.
- Battery capacity is linearly phased in from FY26-FY40 (FY26 capacity is based on PREB mandated procurement schedule in its IRP resolution).
- PR-DRIFT accounts for round-trip efficiency, battery duration, and the minimum state of charge (all user-customizable if desired).
Demand Response Inputs (Residential and Commercial)

Residential and Commercial Sectors (Detailed assumptions on the “User Input_Residential DR” and “User Input_Commercial DR” tabs)

- Users can select “% of [Residential/Commercial] Customers Participating in DR program” and “Max Percent of Participating Load Reduced at Any Given Time” for each DR measure in these sectors. These values are set for FY40 and scaled in based on the selected adoption curve in Input (7) on the dashboard (straight-line, S-curve, logarithmic).

- Each measure has a load profile based on its expected DR resource at each hour of the day (from various sources including EPRI).
**Demand Response Inputs (Industrial)**

**Industrial Sector** *(Detailed assumptions on the “User Input_Industrial DR” tab)*

- Users can select “Total Industrial Demand Response Resource Available by FY 2040 (MW)” and “Percent of Total Industrial Demand Response Resource Available for Emergency Deployment Only”.

- This represents the available or expected industrial self-generation capacity that PREPA is ordered to investigate via the PREB Resolution on the 2019 IRP.

### Industrial Demand Response Measures

- **Year of Analysis (Selected on Dashboard)**: FY 2036

- **Reduction in Industrial Gross Demand Possible at System Peak due to Readily Available DR Resource Available in FY 2036 (%):** 51%

- **Total Industrial Demand Response Resource Available in FY 2040 (MW):** 250.00

- **Percent of Total Industrial Demand Response Resource Available for Emergency Deployment Only in FY 2040:** 50%

### Additional Inputs

- **Peak Net Gross Electricity Demand in FY 2036 (MW):** 2,036.55
- **Gross Industrial Electricity Demand at System Peak in FY 2036 (MW):** 261.18
- **Readily Available Industrial Demand Response Resources Available at System Peak in FY 2036 (MW):** 112.50
- **Emergency Only Industrial Demand Response Resources Available at System Peak in FY 2036 (MW):** 112.50
- **Reduction in Industrial Gross Demand Possible at System Peak due to Readily Available DR Resource Available in FY 2036 (MW):** 134.37
Demand Response Example Calculation

**Demand Response Measure**
- Res. Electric Water Control

**Per Customer Reduction Potential at Peak Hour**
- 5.5 kW/customer

**Program Participation Rates**
- 10% of residential customers opt-in

**Max. % of Participating Load Reduced at Any Given Time**
- System operator allows 50% of participant load at any given time

**Number Residential Customers**
- 1.3m res. customers in Puerto Rico

**DR Resource Available in FY40**
- 358 MW of DR resource available*

**Note:** The values shown here are for illustrative purposes only (e.g., there is no assumption being made that 50% of residential customers will participate in this demand response measure). This calculation could apply for the commercial and industrial sector as well.

* This refers to feasible technical potential based on user inputs, not economic or market potential.
**Note:** The values shown here are for illustrative purposes only and are not definitive forecasts of the DR potential in Puerto Rico. Users can customize inputs based on the design of DR programs to view the impacts for each month from FY21 – FY40.

*Detailed assumptions on the “Forecast_Peak Demand-Annual” and “Forecast_DR Resource” tabs*

### Table 1. Peak Net Gross Demand and Readily Available DR Resource Available for Each Month in Selected FY

<table>
<thead>
<tr>
<th>Month</th>
<th>Peak Net Gross Demand (MW)</th>
<th>Peak Hour</th>
<th>Reduction in Peak Net Gross Demand Possible due to Readily Available DR Resource Available (MW)</th>
<th>Percentage Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1798.44</td>
<td>19</td>
<td>173.93</td>
<td>9.67%</td>
</tr>
<tr>
<td>February</td>
<td>1689.89</td>
<td>21</td>
<td>160.70</td>
<td>9.51%</td>
</tr>
<tr>
<td>March</td>
<td>1884.62</td>
<td>20</td>
<td>165.20</td>
<td>8.77%</td>
</tr>
<tr>
<td>April</td>
<td>1868.43</td>
<td>21</td>
<td>160.70</td>
<td>8.60%</td>
</tr>
<tr>
<td>May</td>
<td>1791.86</td>
<td>21</td>
<td>160.70</td>
<td>8.97%</td>
</tr>
<tr>
<td>June</td>
<td>2033.75</td>
<td>20</td>
<td>165.20</td>
<td>8.12%</td>
</tr>
<tr>
<td>July</td>
<td><strong>2036.55</strong></td>
<td><strong>19</strong></td>
<td><strong>173.93</strong></td>
<td><strong>8.54%</strong></td>
</tr>
<tr>
<td>August</td>
<td>1955.53</td>
<td>19</td>
<td>173.93</td>
<td>8.89%</td>
</tr>
<tr>
<td>September</td>
<td>2004.99</td>
<td>19</td>
<td>173.93</td>
<td>8.67%</td>
</tr>
<tr>
<td>October</td>
<td>1851.33</td>
<td>19</td>
<td>173.93</td>
<td>9.39%</td>
</tr>
<tr>
<td>November</td>
<td>1962.03</td>
<td>18</td>
<td>184.50</td>
<td>9.40%</td>
</tr>
<tr>
<td>December</td>
<td>1862.04</td>
<td>19</td>
<td>173.93</td>
<td>9.34%</td>
</tr>
<tr>
<td>Average Month</td>
<td>1894.96</td>
<td>20</td>
<td>170.05</td>
<td>8.97%</td>
</tr>
</tbody>
</table>

*Month with the highest peak net gross demand in the year will be highlighted yellow*
Note: The values shown here are for illustrative purposes only and are not definitive forecasts of the DR potential in Puerto Rico. Users can customize inputs based on the design of DR programs to view the impacts for each month from FY21 – FY40. (Detailed assumptions on the “Forecast_Peak Demand-Annual” and “Forecast_DR Resource” tabs)
Results: Reduction in Peak Net Gross Demand

**Note:** The values shown here are for illustrative purposes only and are not definitive forecasts of the DR potential in Puerto Rico. Users can customize inputs based on the design of DR programs to view the impacts for each month from FY21 – FY40. (Detailed assumptions on the “Forecast_Peak Demand-Annual” and “Forecast_DR Resource” tabs)

- IRP forecasted annual peak demand used as a baseline.
- Baseline peak net gross demand reduced due to projected EE and DR (net demand already accounts for VRE such as solar PV and wind).
- Results have implications for reduced generation capacity (either avoided new builds or early retirement).
Questions PR-DRIFT Could Help Address

• What is the estimated potential impact on the peak net gross demand (annually or for each month) of technical policies that provide demand response incentives to different sectors?

• For demand response measures that are incentivized in each sector, what is the estimated level of adoption by FY40 needed to achieve specific demand response resource targets?

• In which sector and for which end-uses could DR programs be most effectively targeted in order to have the most benefit to the grid?

• What is the projected VRE and storage capacity needed to meet Act-17 goals, with or without EE and DR?
PR-DRIFT Limitations

- PR-DRIFT does not consider the impact of economic policies or incentive programs on DR adoption (ex. the impacts of a financial incentive from the utility for DR program enrollment); it only considers technical measures.
- PR-DRIFT does not consider the cost of each demand response measure or optimize for the most cost-effective measure.
- PR-DRIFT does not determine the duration of demand response events.
PR-DRIFT Applications
### Example Scenario: Inputs

**Note:** This scenario is based off PREPA 2019 IRP assumptions on DR resource potential for the residential and commercial sectors and PREB assumptions for the industrial sector. This example is meant to illustrate the PR-DRIFT’s functionality.

<table>
<thead>
<tr>
<th>Sector</th>
<th>PREPA/PREB Forecast</th>
<th>PR-DRIFT Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>4.11% of all customers will be participating in AC DR program (direct control) by 2040&lt;sup&gt;1&lt;/sup&gt;.</td>
<td>Measures by End-Use (ON/OFF)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Direct Control of AC (ON)</td>
</tr>
<tr>
<td>Commercial</td>
<td>1.01% of all customers will be participating in AC &amp; lighting controls DR program by 2040&lt;sup&gt;2&lt;/sup&gt;.</td>
<td>Measures by End-Use (ON/OFF)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HVAC Direct Control (ON)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lighting Controls: *LED fixture (ON)</td>
</tr>
<tr>
<td>Industrial</td>
<td>200 MW of DR resource will be available&lt;sup&gt;3&lt;/sup&gt;.</td>
<td>Total Industrial Demand Response Resource Available in FY 2040 (MW)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200.00</td>
</tr>
</tbody>
</table>

<sup>1</sup> PREPA 2019 IRP calculations. Assumptions: 85% of residential customers eligible for AC DR program, number of eligible customers increases by 0.7% annually, 80% of enrolled customers remain enrolled the following year, 1% of new eligible customers enroll in program annually. NREL extrapolated calculations from 2038 to 2040.

<sup>2</sup> PREPA 2019 IRP calculations. Assumptions: 100% of commercial customers eligible for AC and lighting DR program, 0.4% of new eligible customers enroll in program annually for first 5 years, 0.2% of new eligible customers enroll in program annually after first 5 years, 80% of enrolled customers remain enrolled the following year. NREL extrapolated calculations from 2038 to 2040.

<sup>3</sup> PREB Resolution on 2019 IRP estimate on DR resource potential from industrial customers with self generation capacity.
Example Scenario: Results (1 of 3)

Reduction in Residential Gross Demand Possible at System Peak due to DR Resource Available in FY 2040 (%):

0.56%

Reduction in Commercial Gross Demand Possible at System Peak due to DR Resource Available in FY 2040 (%):

0.41%

Reduction in Industrial Gross Demand Possible at System Peak due to Readily Available DR Resource Available in FY 2040 (%):

23%

Result (4)*

Reduction in Peak Net Gross Demand Possible due to Readily Available DR Resource in Selected FY & Month (MW)

67.14

Result (5)

Reduction in Peak Net Gross Demand Possible due to Readily Available DR Resource in Selected FY & Month (%)

3.71%

Result (7)

Additional Reduction in Peak Net Gross Demand Possible due to Emergency Only DR Resource in Selected FY & Month (MW)

179.15

Table 1. Peak Net Gross Demand and Readily Available DR Resource Available for Each Month in Selected FY

<table>
<thead>
<tr>
<th>Month*</th>
<th>Peak Net Gross Demand (MW)</th>
<th>Peak Hour</th>
<th>Reduction in Peak Net Gross Demand Possible due to Readily Available DR Resource Available (MW)</th>
<th>Percentage Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1659.90</td>
<td>19</td>
<td>67.14</td>
<td>4.04%</td>
</tr>
<tr>
<td>February</td>
<td>1563.16</td>
<td>19</td>
<td>67.14</td>
<td>4.29%</td>
</tr>
<tr>
<td>March</td>
<td>1744.54</td>
<td>20</td>
<td>66.19</td>
<td>3.79%</td>
</tr>
<tr>
<td>April</td>
<td>1725.73</td>
<td>21</td>
<td>65.38</td>
<td>3.79%</td>
</tr>
<tr>
<td>May</td>
<td>1657.62</td>
<td>21</td>
<td>65.38</td>
<td>3.94%</td>
</tr>
<tr>
<td>June</td>
<td>1878.67</td>
<td>20</td>
<td>66.19</td>
<td>3.52%</td>
</tr>
<tr>
<td>July</td>
<td>1882.93</td>
<td>19</td>
<td>67.14</td>
<td>3.57%</td>
</tr>
<tr>
<td>August</td>
<td>1810.02</td>
<td>19</td>
<td>67.14</td>
<td>3.71%</td>
</tr>
<tr>
<td>September</td>
<td>1858.10</td>
<td>19</td>
<td>67.14</td>
<td>3.62%</td>
</tr>
<tr>
<td>October</td>
<td>1712.32</td>
<td>19</td>
<td>67.14</td>
<td>3.92%</td>
</tr>
<tr>
<td>November</td>
<td>1819.53</td>
<td>18</td>
<td>68.02</td>
<td>3.74%</td>
</tr>
<tr>
<td>December</td>
<td>1723.26</td>
<td>19</td>
<td>67.14</td>
<td>3.90%</td>
</tr>
<tr>
<td>Average Month</td>
<td>1752.82</td>
<td>19</td>
<td>66.76</td>
<td>3.81%</td>
</tr>
</tbody>
</table>

*Month with the highest peak net gross demand in the year will be highlighted yellow
**Example Scenario: Results (2 of 3)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in Residential Gross Demand Possible at System Peak due to DR Resource Available in FY 2040 (%)</td>
<td>0.56%</td>
</tr>
<tr>
<td>Reduction in Commercial Gross Demand Possible at System Peak due to DR Resource Available in FY 2040 (%)</td>
<td>0.41%</td>
</tr>
<tr>
<td>Reduction in Industrial Gross Demand Possible at System Peak due to Readily Available DR Resource Available in FY 2040 (%)</td>
<td>23%</td>
</tr>
<tr>
<td>Result (4)* Reduction in Peak Net Gross Demand Possible due to Readily Available DR Resource in Selected FY &amp; Month (MW)</td>
<td>67.14</td>
</tr>
<tr>
<td>Result (5) Reduction in Peak Net Gross Demand Possible due to Readily Available DR Resource in Selected FY &amp; Month (%)</td>
<td>3.71%</td>
</tr>
<tr>
<td>Result (7) Additional Reduction in Peak Net Gross Demand Possible due to Emergency Only DR Resource in Selected FY &amp; Month (MW)</td>
<td>179.15</td>
</tr>
</tbody>
</table>

![Graph: Peak Gross Demand by Month in Selected Fiscal Year with Demand Response (DR) Measures](image)

*Fig 3. Peak Gross Demand by Month in Selected Fiscal Year with Demand Response (DR) Measures*
Note: Figure 5 shows the solar PV generation in 2040 assuming that Puerto Rico will meet its renewable portfolio standard (RPS) goal of 60% of electricity generation from variable renewable energy (VRE) by 2040.
Key Takeaways

- The example scenario, based on the PREPA 2019 IRP, is considered a “baseline” scenario with low DR adoption.
  - PR-DRIFT allows for forecasts that result in more DR resource by FY40 and thus the DR impact on load profiles can vary based on user inputs.
- By default, the percentage of each sector load from each end use remains constant throughout the time period analyzed (ex. AC load set to 7% of total residential load).
  - These values can be adjusted by the user to reflect a different percentage breakdown in FY40 (ex. An increased percentage of residential households with AC).
- In general, PR-DRIFT contains standard user inputs and default values. The default values (ex. end-use % of load, end-use profiles, load forecasts, etc.) can also be modified by the user.
Call for Input and Data

We are interested in collaborating with local experts in Puerto Rico and other demand response/load flexibility subject matter experts.

Please reach out with any feedback, questions, or comments.

We are also looking for additional good data sources or references on energy use in Puerto Rico and for estimating the demand response peak shaving/load shifting potential from further measures. Please reach out if you can be of assistance.

Contact

• James.Elsworth@nrel.gov
• Prateek.Joshi@nrel.gov
Future Work

- Incorporate improved Puerto Rico data
  - Survey of residential and commercial end users
  - Data gathering on existing and potential industrial/large commercial back up generator
- Add hourly marginal price forecasts to determine most expensive hours when DR would be most valuable
  - This could also be used to value DR and design incentive programs
  - Could coordinate with ongoing Argonne modeling efforts or upcoming NREL work
  - Locational marginal prices can help determine where DR might be most effective
- Add costs and benefits
  - System implementation costs (administrative and technical)
  - Incentives
  - Avoided generation
  - Value of lost load from load shedding or emergency situations
- Determine hours of the year with largest grid net load ramp rates when DR would also be more valuable
- Direct stakeholder feedback and input from LUMA, PREB, DR administrator, or DR aggregators
- Add Puerto Rico specific end use load curves
  - Can coordinate with ongoing PNNL Puerto Rico building energy modeling
- Estimate impacts of microgrids and implications for specific location of DR resources
- Improve DR estimation to include optimal windows for DR events/Optimize DR dispatch
- Improve battery charge and discharge model
- Add regional granularity
Thank You

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NREL/PR-5R00-81363
Appendix
Acronyms

**BAU**: business-as-usual
**DR**: demand response
**EE**: energy efficiency
**EPRI**: Electric Power Research Institute
**FY**: fiscal year
**IRP**: integrated resource plan
**PR-DRIFT**: Puerto Rico Demand Response Impact and Forecast Tool
**PREB**: Puerto Rico Energy Bureau
**PREPA**: Puerto Rico Electric Power Authority
**PREESAT**: Puerto Rico Energy Efficiency Scenario Analysis Tool
**PV**: photovoltaic
**RPS**: renewable portfolio standard
**SAM**: system advisor model
**VRE**: variable renewable energy