Generation Expansion Planning for 100% Renewable Electricity at Rutgers University

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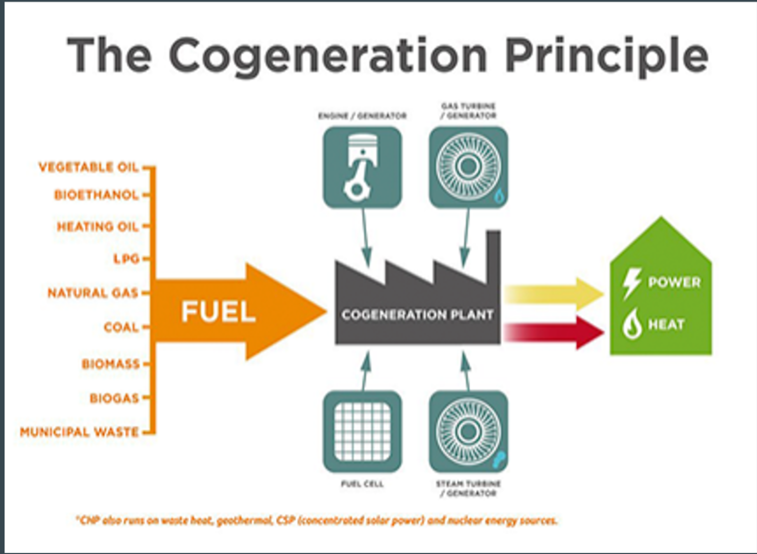
Overview

Goal: Recommendations for Rutgers in creating a climate action plan for carbon neutrality (specifically to address electricity needs with renewable energy).

- *Background:* Rutgers energy use and current progress
- *Methods:* Generation Expansion Planning (GEP) modelling to determine cost of investment in clean electricity infrastructure
- *Results:* Generation summary, optimal investment, and cost compared to baseline scenario
- *Recommendations for Rutgers*
- *References*

Background: Rutgers Energy Consumption and Emissions

- Fossil fuels → climate change
- Rutgers annual energy use (2016-2017)
  - 575,472,963 kWh of electricity
    - 29%: produced through solar power & cogeneration
    - 71%: purchased from PSEG
  - 41,533,308 Therms of gas
  - 216,120.98 gallons of ultra low NOx heating oil
  - Fuel for fleet of 50 buses
- Total estimated greenhouse gas emissions: 646,188 mtCO2e
  - Equivalent to 138,370 passenger vehicles driven for one year
  - Equivalent to 69,775 homes' energy use for one year



Rutgers Energy Use

- Memberships and partnerships with various climate organizations
- Improved carbon footprint through building upgrades and on-campus energy generation (solar and cogeneration)
    - Cogeneration recycles useful heat from electricity generation to provide a building with heat and electricity simultaneously. Cogeneration can be considered renewable if it is fueled by biofuel or biogas, but it still produces greenhouse gas emissions.
- September 2019: Creation of President's Task Force on Carbon Neutrality and Climate Resilience
    - "Investigating possibility" of climate neutrality at Rutgers
    - Work/progress may have stalled due to COVID-19 pandemic
- No numerical commitment to renewable energy or carbon neutrality

Methods

- Generation expansion planning: the planning process to find an optimal long-term plan for constructing new electricity generation capacity while adhering to economic, technical, or political constraints.
  - Derived from optimization model created by Rodgers, et al (2018).
  - Determines the optimal technology investments that can minimize investment, fixed, and variable costs.
  - Constraints: renewable portfolio standard (RPS) of 100% renewable by 2030
- General Algebraic Modeling Systems (GAMS): Mathematical software that can model and solve optimization problems, following the instructions and accounting for the relationships programmed by the user.

Model Components - what was included?

Fixed Parameters

- Fixed costs
- Variable costs
- Investment costs
- Purchase cost
- Initial capacity
- Demand
- Derate
- Construction limit
- Interest rate

Tested Parameters

- Budget limit
- Minimum renewable total
- Total construction limit (fixed tilt solar panels, tracking solar panels; solar thermal; geothermal; fuel cells)

Decision Parameters

- Electricity generation
- Electricity purchased
- Capacity investment

Baseline Case: For Comparison Against Scenarios

Variable	Initial (2018) Value	Annual changes	Rationale
Demand (kWh)	575,472,963 kWh	3% annual increase	Initial demand obtained from Kornitas.
Purchase cost of electricity ($/kWh)	$0.09 per kWh	2% annual increase	Initial cost obtained from Kornitas. 2% increase reflects rate of inflation.
Discount rate (%)	3%	No change	Assumption (Rodgers et al., 2018).

- No additional renewable energy infrastructure
- Meet increasing demand by purchasing from grid
- Average annual cost: 2030: $43,969,503.77 2050: $60,239,611.56
- Total cost (2019-2030): 2030: $571,603,549.03 2050:

Scenario 2030: build infrastructure to power Rutgers with 100% renewable electricity by 2030

- Recommended investment: 92.6 MW of fixed-tilt solar
    - 70.8 MW in the first year
    - 1-2.5 additional MW (fluctuating) after first year
- 463 acres of space needed
    - Total acreage of Rutgers: 2685 acres
- Bonus: carbon neutrality: purchasing offsets would cost $9,651,041.40 from 2020-2030
- Average annual cost: $14,742,739.03
    - First year cost: $133,299,816.09
- Total cost to power Rutgers with 100% renewable electricity from 2020-2030: $163,056,380.50
- Rutgers endowment: $1.33 billion
    - Unrestricted endowment: $532 million: earns interest of ~$21 million annually

Scenario 2050: build infrastructure to power Rutgers with 100% renewable electricity by 2050

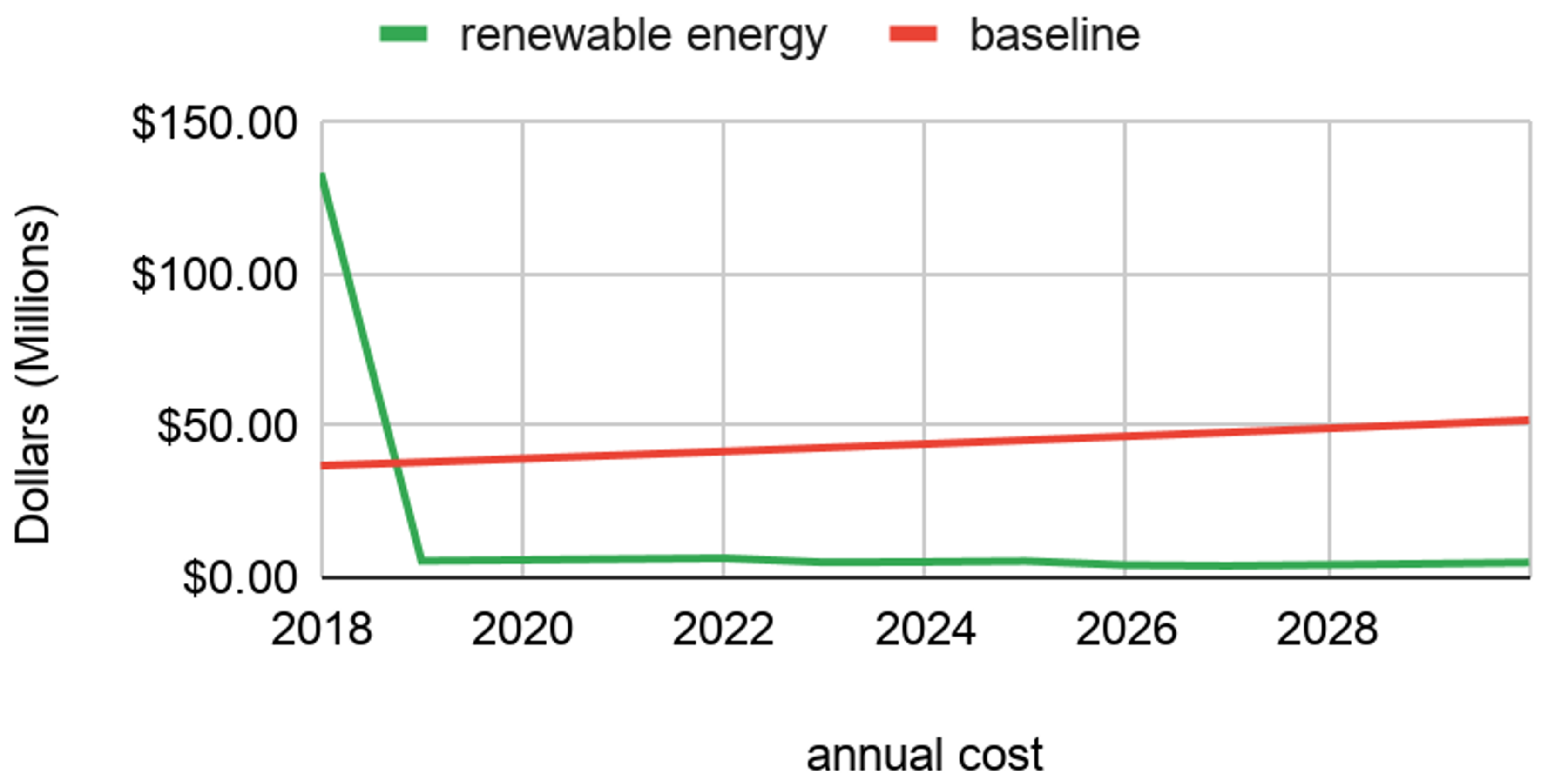
- Recommended investment: 100 MW of fixed-tilt solar, 39.46 MW of solar thermal
  - 75.69 MW of solar fixed-tltl in the first year, 2-5 additional MW from 2021-2028
  - 0.2 - 1.3 MW of solar thermal from 2029-2050
- Average annual cost: $15,001,171.99
  - First year cost: $151,322,680.18
- Total cost: $450,035,159.79
- Rutgers endowment: $1.33 billion
  - Unrestricted endowment: $532 million: earns interest of ~$21 million annually

Scenario Comparisons

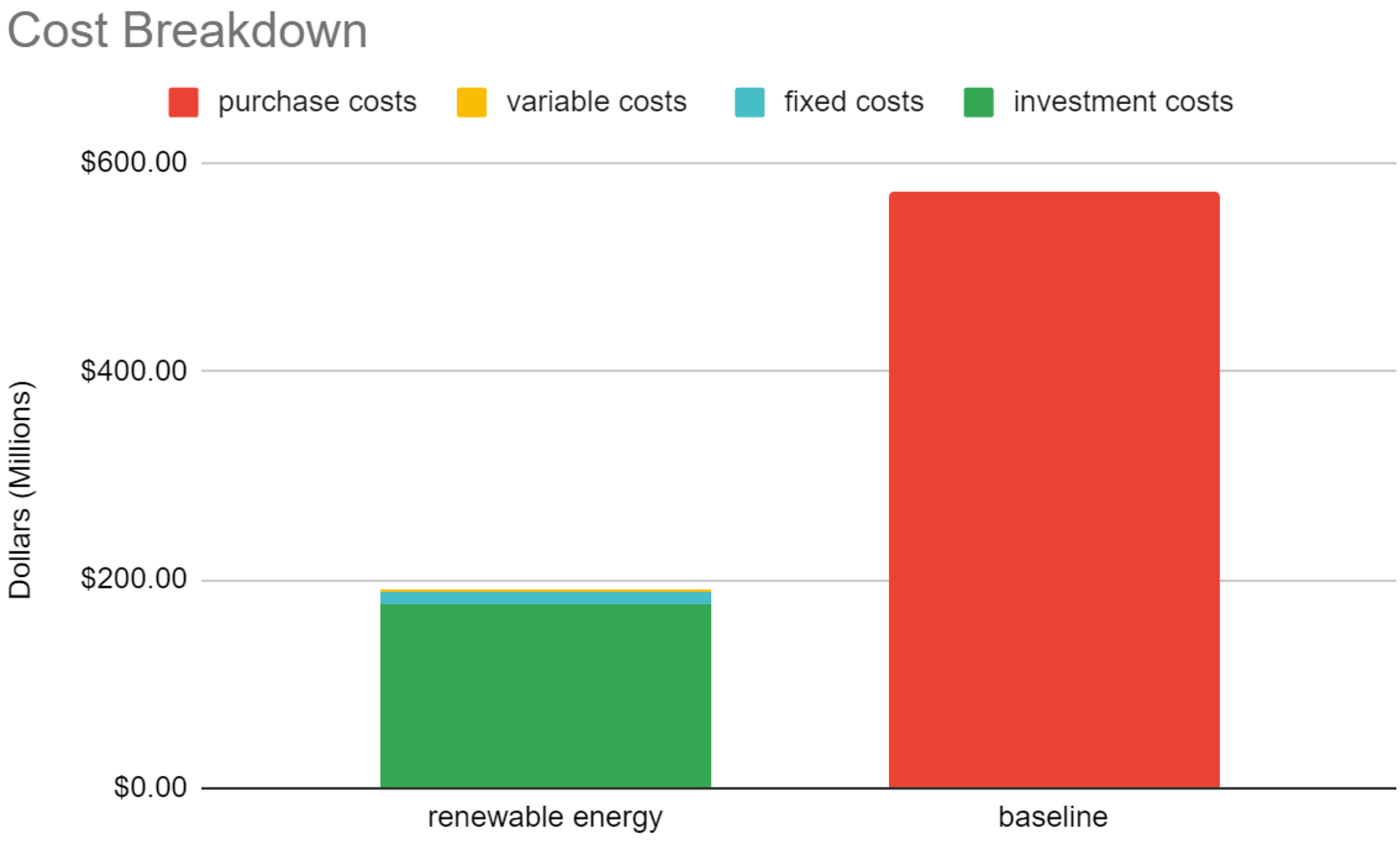
Case	Total cost	Average annual cost	First year cost	New Infrastructure
Baseline 2030	$571,603,549.03	$43,969,503.77	$36,679,474.98	None
Renewable 2030	$163,056,380.50	$14,742,739.03	$133,299,816.09	92..6 MW fixed-tilt solar
Baseline 2050	$1,927,667,569.80	$60,239,611.56	$36,679,474.98	None
Renewable 2050	$450,035,159.79	$15,001,171.99	$51,322,680.18	100 MW fixed-tilt solar, 39.46 MW solar thermal

2030

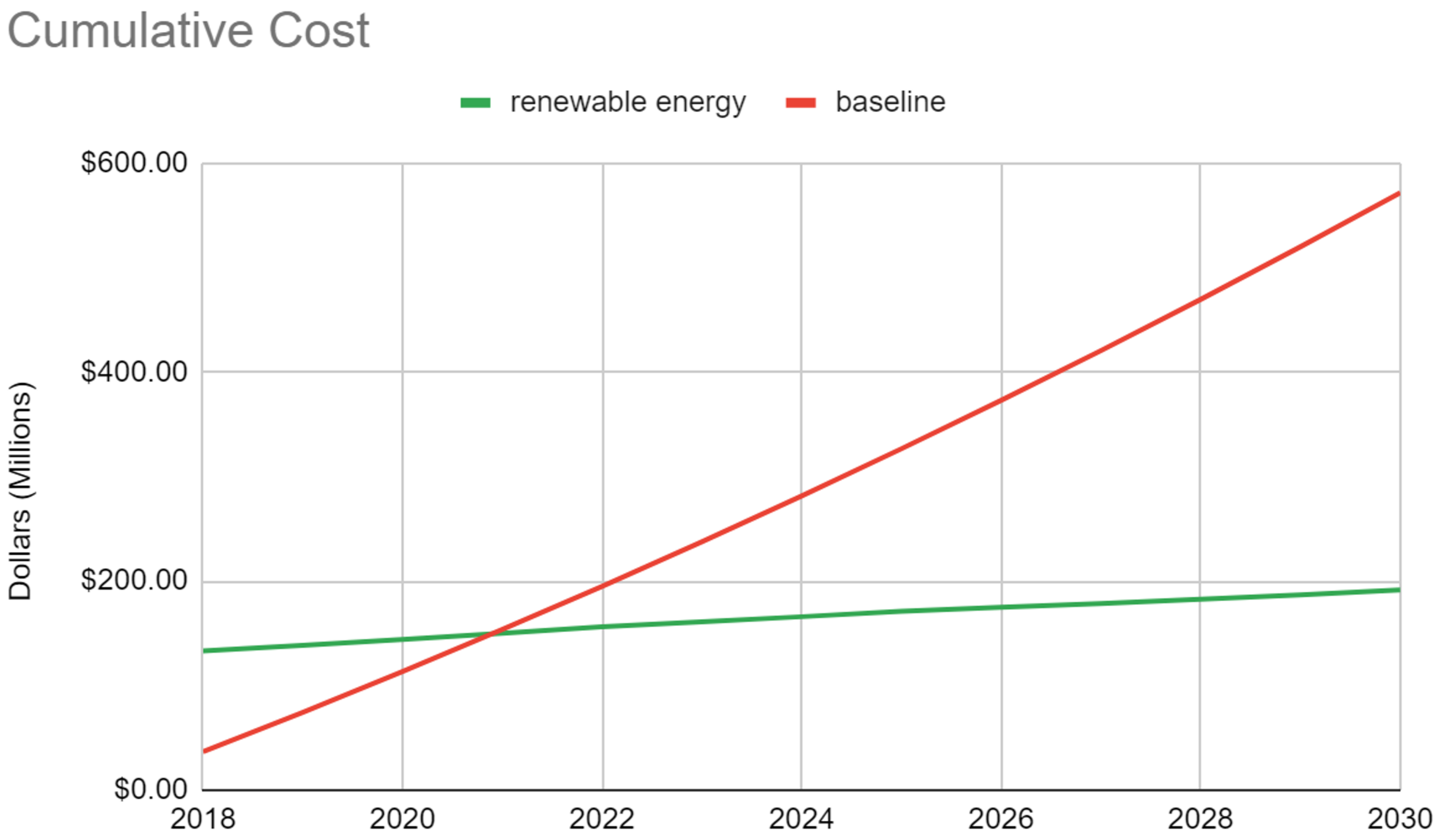
Annual Cost



2030


Cost Breakdown
purchase costs
variable costs
fixed costs
investment costs
$600.00
$400.00
$200.00
$0.00
Dollars (Millions)
renewable energy
baseline

2030


Cumulative Cost
renewable energy
baseline
Dollars (Millions)
$600.00
$400.00
$200.00
$0.00
2018
2020
2022
2024
2026
2028
2030

Recommendations for Rutgers

1. Participate in AASHE STARS.
   a. “Provides a clear road map for a campus to reach a benchmark level at any time” (Martin & Samels, 2012).
   b. Identify areas of improvement and compare with other universities

2. Establish an Office of Sustainability to organize sustainability efforts.

3. Include sustainability in the campus master plan.

4. Invest in energy efficiency to reduce demand.

5. Use energy efficiency savings to invest in renewable energy, storage, and energy management - especially fixed-tilt solar (the most economically efficient).

6. Create a culture of sustainability.

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