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Edward J. Bloustein School
of Planning and Public Policy

Economic Thinking and Tools to Value the Acceleration of Technology in Residential GENSETS

GENerators for Small Electrical and Thermal Systems (GENSETS) Kickoff Meeting

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Center for Energy, Economic and Environmental Policy

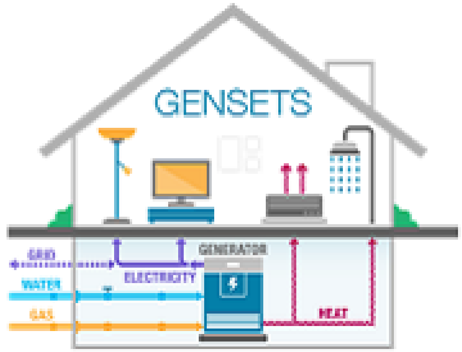
Frank A. Felder, Ph.D.

ffelder@rci.rutgers.edu

OVERVIEW 1: Related Prior and Ongoing Work

1. Cost-effectiveness analysis of increasing solar PV penetration on distribution systems (US DOE SUNSHOT)
2. Cost-benefit analysis of biopower, energy storage, and CHP (NJ Board of Public Utilities)
3. Macroeconomic analysis of energy resiliency investments (NJ Energy Resilience Bank)
4. Future of the grid under climate change (US National Science Foundation)

OVERVIEW 2: General Economic Framework



SOCIETY

COSTS

- ✓ Incentives
- ✓ Gas T&D costs (for additional supply of gas to CHP)

BENEFITS

- ✓ Increased Reliability resulting in community benefits such as storm shelter etc.
- ✓ Avoided electric T&D costs
- ✓ Reduction in air emissions

OWNER

COSTS

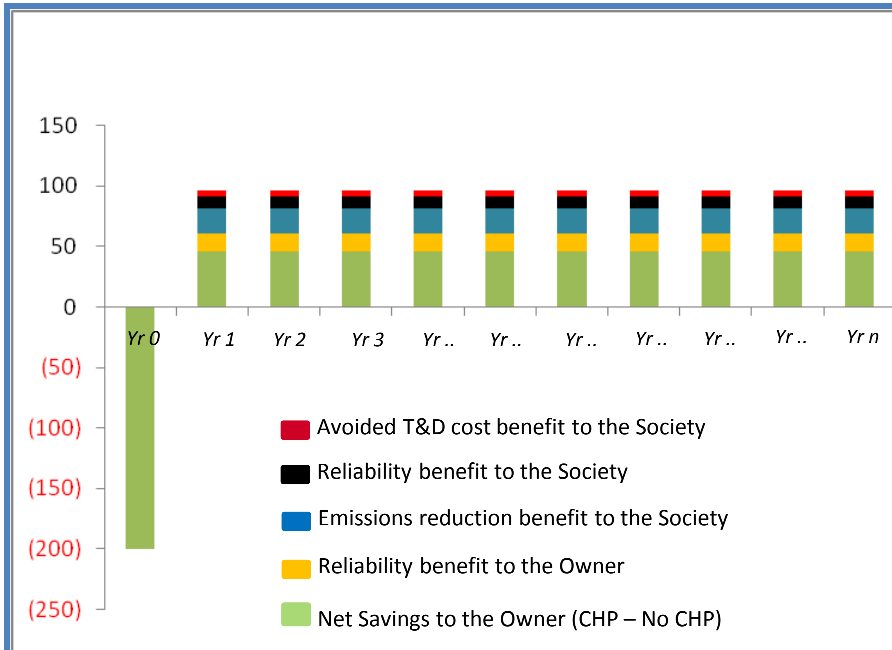
- ✓ Capital Costs
- ✓ Fuel Costs
- ✓ O&M Costs

BENEFITS

- ✓ Increased Reliability
- ✓ Savings on electricity supply bills (after paying for standby charges)

There could be some macroeconomic effects (such as job growth) which could be positive or negative

Net Benefits to Society (Quantifying Costs & Benefits)



OVERVIEW 3: Techno-economic insights for consideration

1. Engineering efficiency and economic efficiency are related but are not identical

2. Economic analysis depends on the decision-maker

3. Incentives matter, i.e., they change behavior
    1. Build in data collection and economic analysis from the beginning
    2. Measure actual performance over long periods of time

4. Cost-benefit analysis vs. Net Present Value vs. Optimization

5. Optimizing the average may not result in optimality

6. Transaction costs matter

PERFORMANCE 1: Target Costs and Performance Metrics

1. 40% efficiency
2. ≤ $3,000/kWe
3. ≥ 10 year life
4. Emissions
    1. Particulate Materials (PM) ≤ 0.4 g/kWh
    2. CO2eq ≤ 1100 lb/MWh
    3. Volatile Organic Compounds (VOCs) ≤ 0.02 lb/MWh
    4. Carbon Monoxide (CO) ≤ 0.10 ib/MWh
    5. Nitrogen Oxice (NOx) ≤ 0.07 ib/MWh
    6. Noise ≤ 55dB at 3 feet

Reference GENSET FOA, Oct. 16, 2014, pp. 5-9

"ARPA-E recognizes that installing and maintaining the electricity grid requires high fixed-cost investment in wires, transformers, etc. Currently, residential customers pay for these costs predominantly through their $/kWh retail electricity rates. As the penetration of distributed generation continues to grow, traditional utility rate structures that recover fixed costs through variable rates can cause problems such as utility revenue inadequacy and cross-subsidization between customers. Projecting the actual cost of grid electricity into a future with widespread CHP penetration is highly uncertain, since customers who install CHP systems would continue to rely on a connection from the electrical grid and they will continue to pay a portion of the cost of grid installation and maintenance. <u>A lower bound for comparison would be to use the current wholesale electricity price in the analysis ($0.06 to $0.10 per kWh), which with a 7-year payback indicates that the CAPEX would likely need to be below $2,000 for the 40% generator.</u>

In light of the considerations above, the GENSETS FOA sets a CAPEX target of $3,000 and a system lifetime of 10 years. These targets provide a fair balance between payback time for the consumer in light of uncertainty in future electricity prices associated with high CHP penetration." (p. 8, emphasis added)

PERFORMANCE 2: Targets should be set on future technologies, not existing

Lower than all of the following:

Grid at the time GENSETS are commercially viable

Solar PVs plus storage or PVs plus extensive demand response

Smart grid with extensive energy efficiency and demand response

Changes in utility rate design to higher fixed components and lower variable components

COSTS 1: Need to include all costs

1. Grid costs
2. Avoided T&D costs
3. Blackstart and islanding costs
4. Value of loss of load
5. Transaction costs and non-economic factors (e.g., home owners' insurance)
6. Cooling costs of advanced absorption chillers
7. Natural gas leakage and other environmental externalities
8. Net emissions may decrease but their location is now closer to population centers

COSTS 2: Project complexity and location does have an effect on the installed capital costs

Applicant Name (Source: BPU Order dated Dec 19, 2013 and Jan 23, 2013)	**Installed Capacity (MW)**	**Prime Mover Type**	**Application quoted – Capital Cost ($/kW)**	**Comparable Tech Size**	**National Average Capital Cost ($/kW) ***	**Source**	**Factor** (times the national average costs)
AtlantiCare Regional Medical	1.10	RE	3,182	1 MW	1,671	SENTECH, 2010	1.9
Monmouth Medical Center	3.00	RE	2,222	3 MW	1,515	ICF, 2012	1.5
New CMC	3.00	RE	2,305	3 MW	1,515	ICF, 2012	1.5
Bristol Meyer's Squibb	4.11	RE	2,263	5 MW	1,515	ICF, 2012	1.5
UMM Energy Partners	5.67	CT	4,680	5.67 MW	1,336	SENTECH, 2010	3.5
Nestle Inc.	7.96	CT	1,905	10 MW	1,588	ICF, 2012	1.2

** $2012 adjusted @2.2% GDP Deflator*

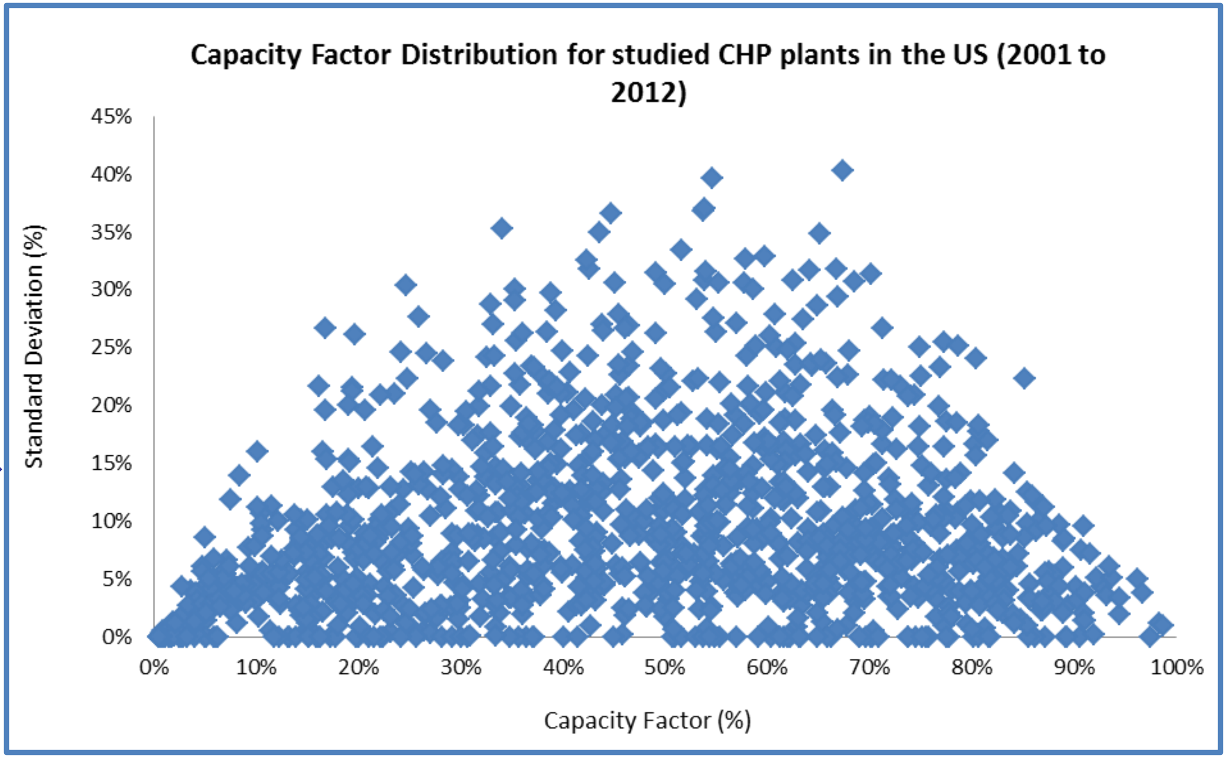
1. Industry experts advise caution while using **'plain vanilla' costs** in widely quoted reference studies, such as the EPA Catalog and others as mentioned in the table above.
2. EPA Catalog notes that " ….. It should be noted that **installed costs can vary significantly** depending upon on the scope of the plant equipment, geographical area, competitive market conditions, special site requirements, emissions control requirements, prevailing labor rates, whether the system is a new or retrofit application, and whether or not the site is a green field or is located at an established industrial site with existing roads, water, fuel, electric etc."

COST 3: Actual performance may be lower than assumed performance: e.g., capacity factor of CHP plants

CHP Database
(plants with installed capacity > 1 MW)

Capacity Factor calculation: for a particular year, for a particular plant

$$CF = \frac{Actual\ Generation\ (kWh)}{Plant\ Capacity\ (KW) * 8760}$$



COST 4: Studies show an extremely wide range of avoided T&D costs

Avoided Energy Supply Costs in New England: 2013 Report by Synapse Energy Economics, Inc.

Company	Year $	Transmission $kW-year	Distribution $kW-year	Methodology
CL&P	2013	$1.30	$30.94	ICF Tool
WMECO	2011	$22.27	$76.08	ICF Tool
NSTAR	2011	$21.00	$68.79	ICF Tool
National Grid MA	2013	$88.64	$111.37	ICF Tool
National Grid RI	2013	$20.62	$20.62	ICF Tool
PSNH	2013	$16.70	$53.35	ICF Tool
United Illuminating	2013	$2.64	$47.82	B&V Report
United MA	2013	NA	$171.15	ICF Tool
United NH	2013	$73.03	$29.26	ICF Tool
Vermont (statewide)	2012	$48.00	$102.00	Historical
Burlington Electric Deptt.	2012	$48.00	-	Historical

- *ICF Tool = ICF workbook developed in 2005*
- *B&V Report = United Illuminating Avoided Transmission & Distribution Cost Study Report, Black & Veatch, September 2009*

1. For the 2013 study report, Synapse surveyed the sponsoring electric utilities (table ref)
2. ICF Tool / workbook was developed by ICF for the 2005 Avoided Energy Supply Costs study
3. The tool was an Excel workbook, which allows participants to calculate their marginal costs
4. Participants need to provide:
    1. T&D investments – 15 historical years and 10 forecast years (e.g. $100 historical, $50 forecast)
    2. Specify the share of total investment which is related to load growth (default entry 50%)
    3. Estimates for carrying charges – which include insurance, taxes, depreciation, interest and O&M (e.g. 20%)
    4. Peak load growth – 15 historical years and 10 forecast years (e.g. incremental growth historical 10 KW, and incremental growth forecast 5 KW)
    5. Marginal cost historical = (100 *50% * 20%)/10 = 1
    6. Marginal cost forecast = (50 *50% * 20%)/ 5 = 0.5
    7. Avoided capacity cost = 1.5 $kW-year

COSTS 5: Several parameters determine the extent of reliability benefits achieved by blackstart (b/s) & islanding

Annual Expected Net Benefits of B/S and Islanding Capability = Benefits - Costs

Benefits:

- *Annual Probability of Outage*
  x
- *Duration of Outage (hrs)*
  x
- *GENSET System Size (MW)*
  x
- *VOLL ($/MWh)*

Costs:

- *Annual Cost of Black Start & islanding ($/MW)*
- *Annual Variable Costs (Fuel + O&M) ($/MWh)*

NPV of this annual expected net benefit can be allocated to GENSET owner and society

Epistemic Uncertainty (uncertainty in our knowledge)

Probability of Outage - Range **x** Duration of Outage - Range **x** GENSET Size **x** GENSET Availability **x** VOLL - Range **-** Cost

Aleatory Uncertainty (uncertainty in measurement)

Fixed + Variable (includes black-start & islanding costs)

COST 6: Probability and duration of outages are difficult to predict

Source of information:

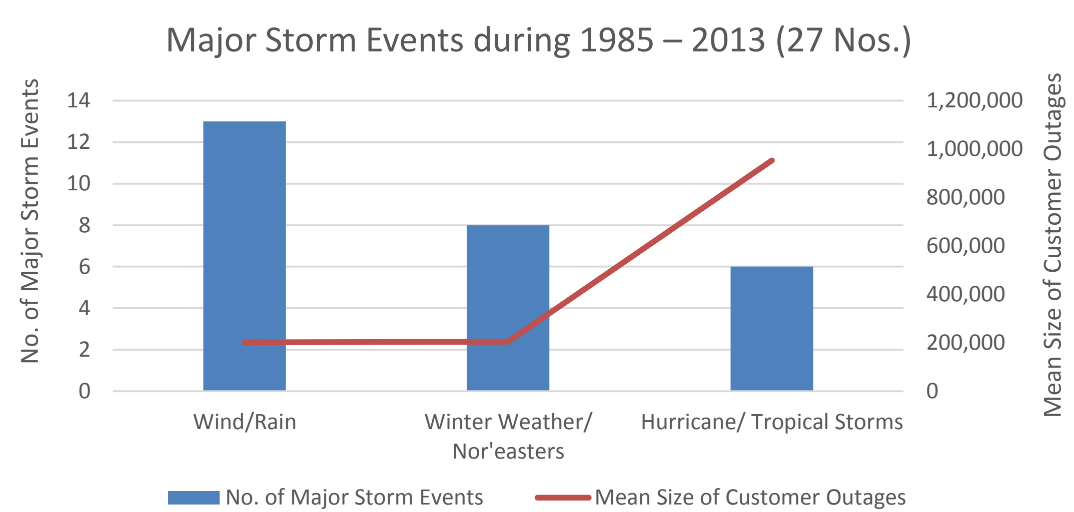
- **NOAA Storm Events Database** used as starting point for fields of data to be collected
- **Bayshore Regional Watershed Council** mainly lists hurricanes and tropical storms to effect NJ

Storm Events Database (1985-2013)

- Sustained outages (lasting > 5 mins)
- Events with >1,000 outages/event
- "Major events" >100,000 outages/ event

Outages refer to outage for a meter and not for a consumer

Events with >1000 outages per event during 1985-2013	# of Total Events	# of Cumulative Affected Customers	% of reported events	Mean size of customer outages
Wind/Rain	96	4,430,900	67.1	46,155
Winter Weather/Nor'easters	22	2,018,200	15.4	91,736
Ice Storm	5	95,500	3.5	19,100
Tornado	2	121,000	1.4	60,500
Lightning	9	175,800	6.3	19,533
Hurricane/Tropical Storm	9	5,768,500	6.3	640,944
Total	143	12,609,900		



OPTIMIZING: Transitioning from Cost-benefit Analysis to Net Present Value to Optimization

1. Optimization will be needed to model the economic benefits and costs of GENSETS under high penetration scenarios

2. Optimizing for the average may not result in the optimal on average
   1. Residential housing stock is extremely varied (single vs. multi-family, condition, age, range of urban to rural, types of home owners
   2. Accounting for uncertainty

SUMMARY

- Next Steps
- Questions and answers