



Edward J. Bloustein School  
of Planning and Public Policy

# Costs and Benefits of Combined Heat and Power

June 19, 2013

Draft v.2

*With minor modifications to the presentation made to the NJ CHP/FC Working Group on 19 June 2013 (marked in red)*

Center for Energy, Economic and Environmental Policy,  
Rasika Athawale and Frank A. Felder

## AGENDA

1. Context of a Cost-Benefit Analysis (CBA)
2. Approach for analysis
  - a. Caveats
  - b. Database for major Technical & Financial assumptions
  - c. Methodology for cost-benefit calculations
  - d. Major assumptions requirement from stakeholders
3. Summary of what has been completed
4. Next Steps

***We would like to thank Gearoid Foley, Richard Sweetser and the Mid-Atlantic Clean Energy Application Center for their time and valuable inputs.***

***Note: References used by CEEEP can be found at <http://policy.rutgers.edu/ceep/chp>***

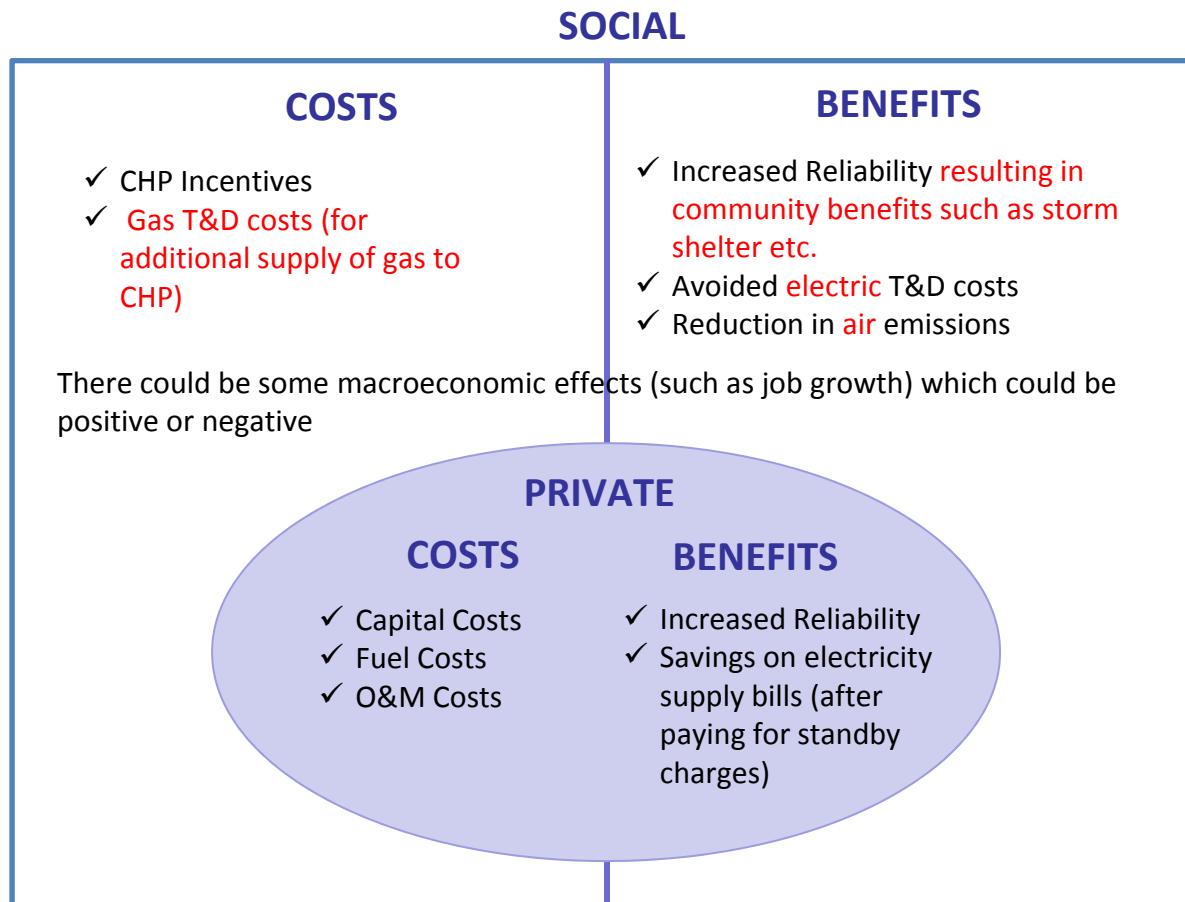
## General Remarks on Cost-benefit Analysis

1. Cost-benefit analysis (CBA) is an economic tool that reduces costs and benefits that occur over time into a numerical score
  - a. Benefit/Cost (B/C) ratio, Net Present Value (NPV), Return on Investment (ROI), Payback Period
  - b. The time value of money and the risk associated with the investment are both captured in the discount rate
2. CBA is relatively easy to use but also easy to misuse
3. CBA only accounts for efficiency but not other values and objectives such as equity and therefore should inform public policy but not be dispositive
4. A CBA can be conducted from different perspectives, e.g., from that of a project developer or society

## Private vs. Social Costs and Benefits

1. Economists distinguish between private costs and benefits and social costs and benefits
2. Actions taken by private individuals or entities that result in society bearing costs or receiving benefits are called externalities
3. A CBA conducted from a private perspective may be different than from a social perspective
4. In a social CBA, payments from one part of society to another are transfers not benefits or costs; of course to the individual parties they are considered benefits or costs
5. The above are incorporated in NJ's CBA of energy efficiency programs

## Private vs. Social Costs and Benefits (contd.)



*The above does not consider impact of SBC & SUT (discussed on next slide)*

# Private vs. Social Costs and Benefits – SBC & SUT

	without CHP		with CHP	
	e <sup>-</sup>	NG	e <sup>-</sup>	NG
Societal Benefits Charge (SBC)	<ul style="list-style-type: none"> <li>SBC Cents/kWh</li> </ul>	<ul style="list-style-type: none"> <li>SBC \$/therm</li> </ul>	<ul style="list-style-type: none"> <li>Reduced e-purchase from grid</li> <li>SBC collection is reduced ↓</li> </ul>	<ul style="list-style-type: none"> <li>Increased NG purchase from grid</li> <li>SBC collection decrease ^ ↓</li> </ul>
NJ Sales & Use Tax (SUT)	<ul style="list-style-type: none"> <li>7 % applied to all sub-types of charges including SBC</li> </ul>	<ul style="list-style-type: none"> <li>7 % applied to all sub-types of charges including SBC</li> </ul>	<ul style="list-style-type: none"> <li>Reduced collection of tax due to ↓ lower e-consumption from grid</li> </ul>	<ul style="list-style-type: none"> <li>Increased collection of tax due to ↑ higher NG consumption from grid</li> </ul>

*^ assuming all electricity generated is self-consumed*

# Private vs. Social Costs and Benefits – Air Emissions (1)

without CHP			with CHP		
CO <sub>2</sub> emissions from e <sup>-</sup> generation			CO <sub>2</sub> emissions from e <sup>-</sup> generation		
Fuel Type	% Marginal Run (2012) PJM State of the Market 2012*	US Avg. Emissions Rate CO <sub>2</sub> (lbs/MWh) EPA*	CHP Type	Emissions Rate CO <sub>2</sub> (lbs/MWh) #	Source of Information
Coal	58.8%	2,249	RE 1 MW	1,142	EPA Catalog
Gas	30.4%	1,135	RE 3 MW	1,110	EPA Catalog
Oil	6.0%	1,672	RE 5 MW	1,024	EPA Catalog
Wind	4.2%	0	GT 10 MW	1,404	EPA Catalog
Other	0.5%	0			
Municipal Waste	0.1%	2,988			
Average 2012		1,770			

# does not include reductions for thermal load

\* For references pl see the last slide

# Private vs. Social Costs and Benefits – Air Emissions (2)

without CHP			with CHP		
NO <sub>x</sub> emissions from e <sup>-</sup> generation			NO <sub>x</sub> emissions from e <sup>-</sup> generation		
Fuel Type	% Marginal Run (2012) PJM State of the Market 2012	US Avg. Emissions Rate NO <sub>x</sub> (lbs/MWh) EPA	CHP Type	Emissions Rate NO <sub>x</sub> (lbs/MWh) #	Source of Information
Coal	58.8%	6.0	RE 1 MW	1.49	EPA Catalog
Gas	30.4%	1.7	RE 3 MW	1.52	EPA Catalog
Oil	6.0%	4.0	RE 5 MW	1.24	EPA Catalog
Wind	4.2%	0	GT 10 MW	0.65	EPA Catalog
Other	0.5%	0			
Municipal Waste	0.1%	5.4			
Average 2012		4.3			

# does not include reductions for thermal load

# Private vs. Social Costs and Benefits – Air Emissions (3)

without CHP				with CHP			
SO <sub>x</sub> & Hg emissions from e <sup>-</sup> generation				SO <sub>x</sub> & Hg emissions from e <sup>-</sup> generation			
Fuel Type	% Marginal Run (2012) PJM State of the Market 2012	US Avg. Emissions Rate SO <sub>x</sub> (lbs/MWh) EPA	US Avg. Emissions Rate Hg (TPY i.e. tons per year) EPA *	CHP Type	Emissions Rate SO <sub>x</sub> (lbs/MWh) #	Emissions Rate Hg (TPY) #	Source of Information
Coal	58.8%	13.0		RE 1 MW	0	0	EPA Catalog
Gas	30.4%	0.1		RE 3 MW	0	0	EPA Catalog
Oil	6.0%	12.0		RE 5 MW	0	0	EPA Catalog
Wind	4.2%	0		GT 10 MW	0	0	EPA Catalog
Other	0.5%	0					
Municipal Waste	0.1%	0.8					
Average 2012		8.4	53.0				

**Particulate Matter (PM) emissions needs to be included**

\* For references pl see the last slide

## General Remarks on Combined Heat and Power (CHP)

1. CHP applications require the right combination of thermal and electric load
2. Engineering efficiency is different from economic efficiency
3. CHP facilities require black start **and islanding** capabilities if they are to run when the electric power system is unavailable
4. CHP applications are site specific; a generic analysis is a useful starting point, but individual applications should be examined in detailed

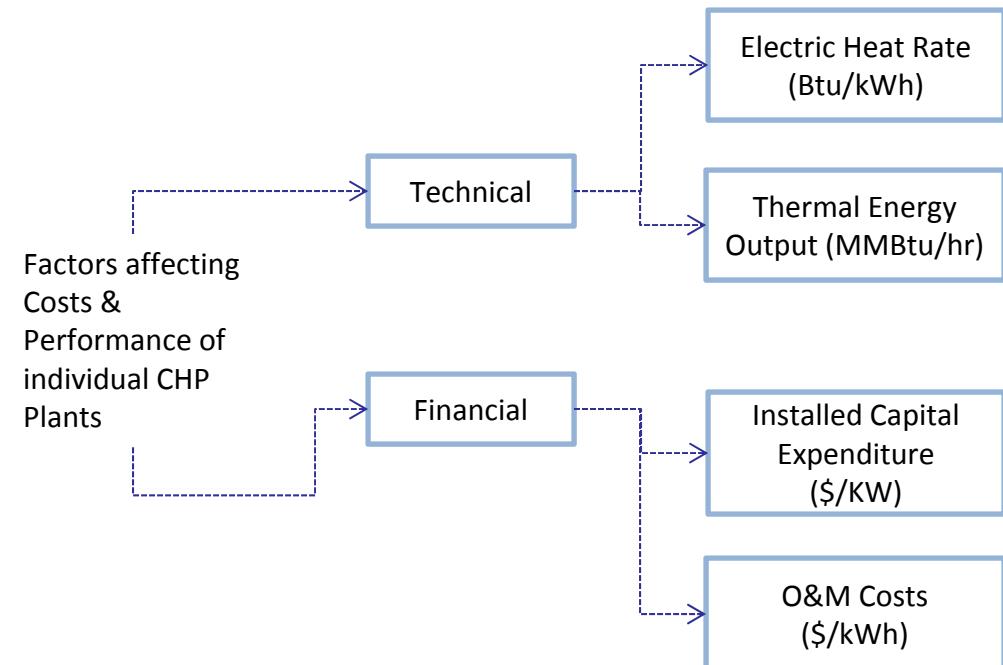
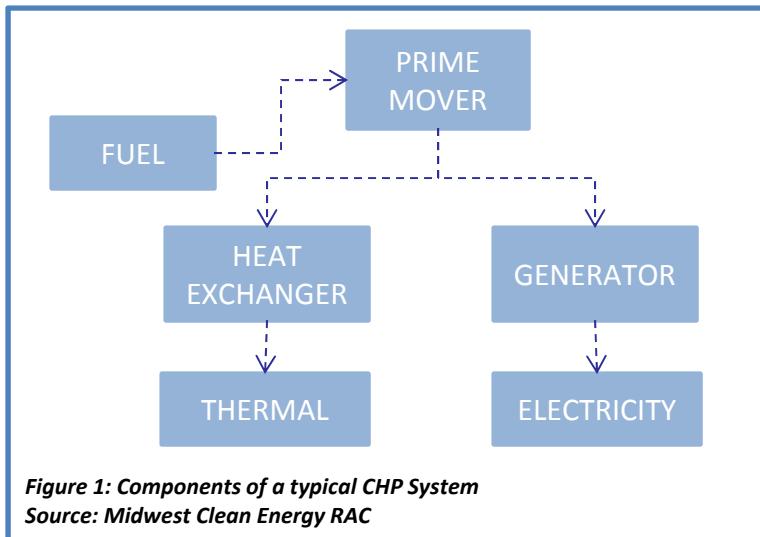
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1. Context of a Cost-Benefit Analysis (CBA)
2. Approach for analysis
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## CAVEATS

1. The analysis presented illustrates the capabilities of the database and model; once feedback is obtained from BPU Staff and stakeholders, preliminary results will be generated
2. Some important and large uncertainties exist in the assumptions such as:
  1. Avoided transmission and distribution costs
  2. Environmental externalities
  3. Value of loss of load
3. For a given standby charge, the CHP CBA analysis can inform policymakers about how that would affect private investment in CHP, but the CHP CBA cannot determine the appropriate standby charge
4. The CHP CBA model could be used to refine the 1,500 MW of CHP goal but that may not be necessary

# Key Input parameters for CHP Economics



We have compiled a database of various CHP technologies and their corresponding technical and financial factors

# Database capturing CHP Technology Type and key input parameters

S.N.	CHP Technology	Specification	Electric Capacity (kW)	Electric Heat Rate (Btu/kWh)	Thermal Energy Output (MMBtu/hr)	Total Installed Costs (\$/kW)	O&M Costs (\$/kWh)	
1	ICF International Incorporated Catalog #	SENTECH, EPA CHP	ICF International Incorporated Catalog #	SENTECH, EPA CHP	ICF International Incorporated Catalog #	SENTECH, EPA CHP	ICF International Incorporated Catalog #	
2	al. Inc. @							
3	CHP Policy C&I CHP US Analytic and Technology Environment 2011-2030 Out and About Assessment Report, Feb 2012 (for California)	CHP Policy C&I CHP US Analytic and Technology Environment 2011-2030 Out and About Assessment Report, Feb 2012 (for California)	CHP Policy C&I CHP US Analytic and Technology Environment 2011-2030 Out and About Assessment Report, Feb 2012 (for California)	CHP Policy C&I CHP US Analytic and Technology Environment 2011-2030 Out and About Assessment Report, Feb 2012 (for California)	CHP Policy C&I CHP US Analytic and Technology Environment 2011-2030 Out and About Assessment Report, Feb 2012 (for California)	CHP Policy C&I CHP US Analytic and Technology Environment 2011-2030 Out and About Assessment Report, Feb 2012 (for California)	CHP Policy C&I CHP US Analytic and Technology Environment 2011-2030 Out and About Assessment Report, Feb 2012 (for California)	
4	Report, Feb 2012 (for California)							
5	<b>1 Reciprocating</b>							
6	1a Small - Rich Burn with 3 wsg	100 kW	12,637		12,000	0.67	0.61	2,750
7	1b Gas Reciprocating Engine	200 kW			9,686		2.16	2,210
8	1c Diesel Reciprocating Engine	300 kW		9,618		0.00		1,940
9	1d Diesel Reciprocating Engine (equipped with SCR for NOx control and DPF for PM control)	300 kW		10,124		1.20		1,804
10	1e Gas Reciprocating Engine	304 kW			11,404	2.02		
11	1f Small - Lean Burn	800 kW	9,760	9,760		3.44	4.30	1,900
12	1g Gas Reciprocating Engine	1000 kW		9,097		3.32		1,600
13	1h Gas Reciprocating Engine	2000 kW		9,394		8.80		1,400
14	1i Large - Lean Burn	3000 kW	9,800	9,492		12.60	10.53	1,450
15	1j Large - Lean Burn	5000 kW	8,406	8,798		15.37	15.23	1,450
16	<b>2 Gas Turbines</b>							
17	2a Gas Turbine	160 kW			16,047		8.31	
18	2b Gas Turbine	3000 kW	14,085		17,841		2,450	
19	2c Gas Turbine	310 kW			13,893	25.102		1,311
20	2d Gas Turbine Reuperated	4400 kW			10,054	14,012		1,369
21	2e Gas Turbine	5457 kW			12,312		28.28	
22	2f Gas Turbine	5670 kW					1,279	1,314
23	2g Gas Turbine	10000 kW	11,765			46.74		1,520
24	2h Gas Turbine	10239 kW					49.1	1,288
25	2i Gas Turbine	25000 kW		9,945			90.34	1,057
26	2j Gas Turbine	40000 kW	9,220			127.56		1,770
27	<b>3 Microturbines</b>							
28	3a Microturbine	30 kW			15,075		0.17	2,970
29	3b Microturbine	65 kW	13,950	12,943	13,831	0.362	0.375	3,000
30	3c Microturbine	105 kW	12,247			0.789		2,430
31	3d Microturbine	200 kW			10,670	0.744		2,440
32	3e Microturbine	250 kW			13,080		1.2	
33	3f Microturbine	925 kW	12,247			3.345		2,800
34	<b>4 Fuel Cells</b>							
35	4a PEM	6 kW		9,383		0.0213		15,000
36	4b PEM	10 kW			10,970		0.04	9,100
37	4c SOFC	105 kW			8,634		0.04	NA
38	4d PEM	200 kW			9,750		0.72	NA
39	4e PAFC	200 kW			9,480		0.085	6,330
40	4f PAFC (200 / 400)	200 kW	9,975			0.522		5,000
41	4g MCFC	300 kW	8,022	8,022		0.644	0.4800	5,600
						0.48		7,495
							\$0.035	5,560
							\$0.035	0.0454
								0.035

Complete Database and References used by CEEEP can be found at  
<http://policy.rutgers.edu/ceep/chp>

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1. ICF International Inc., CHP Policy Analysis and 2011-2030 Market Assessment Report, Feb 2012 (prepared for California Energy Commission)
2. SENTECH Incorporated, C&I CHP Technology Cost and Performance Data Analysis for EIA, June 2010 (prepared for Energy Information Administration)
3. EPA CHP Catalog, Combined Heat and Power Partnership, Dec 2008 (study done by Energy and Environmental Analysis – an ICF International Company)

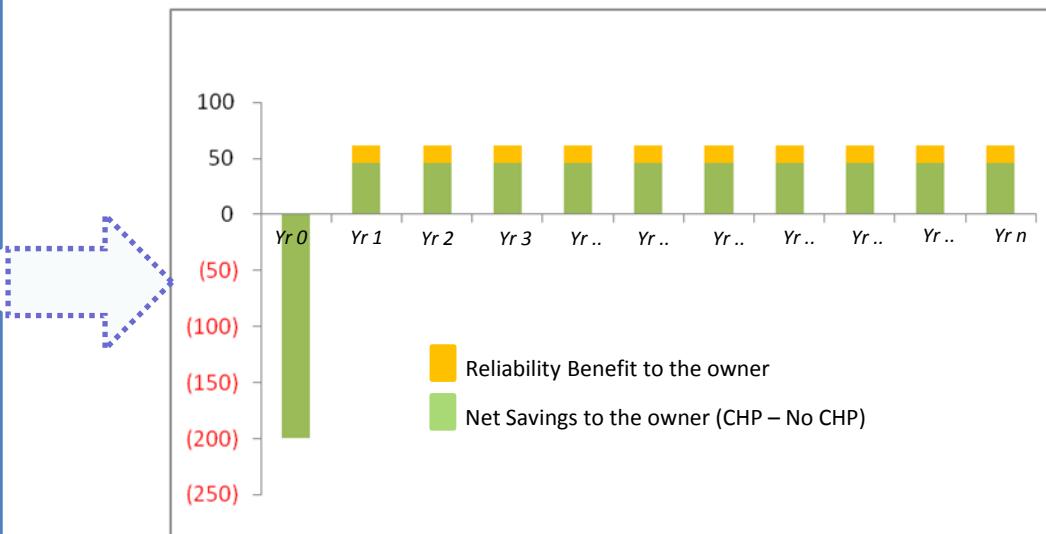
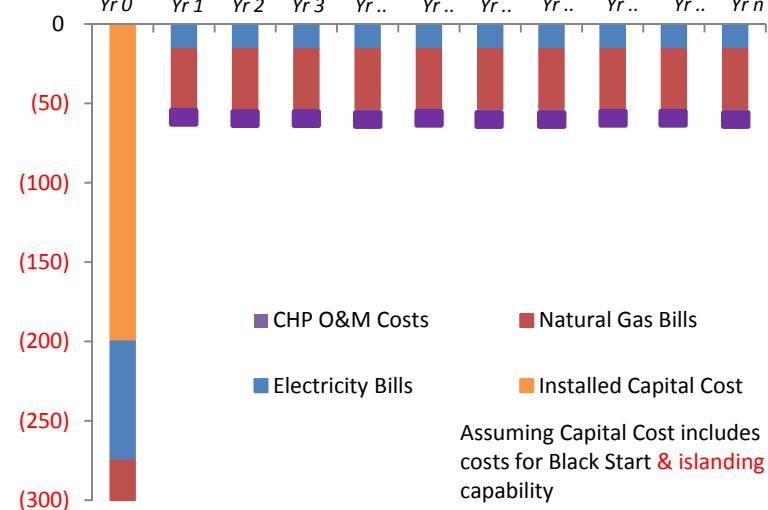
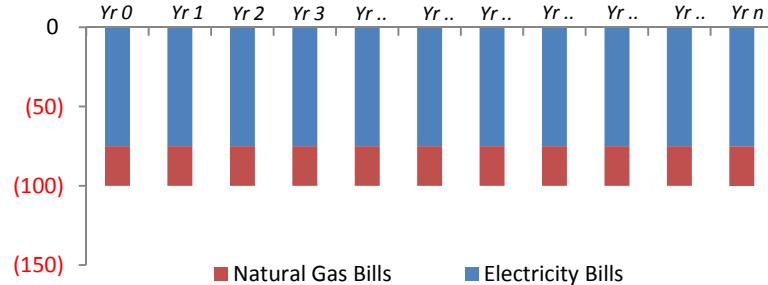
## Observations

1. Numbers from referred studies are for the whole of the US and not for the state of NJ
2. Numbers reported assume ‘simple’ installations and therefore no major installation costs

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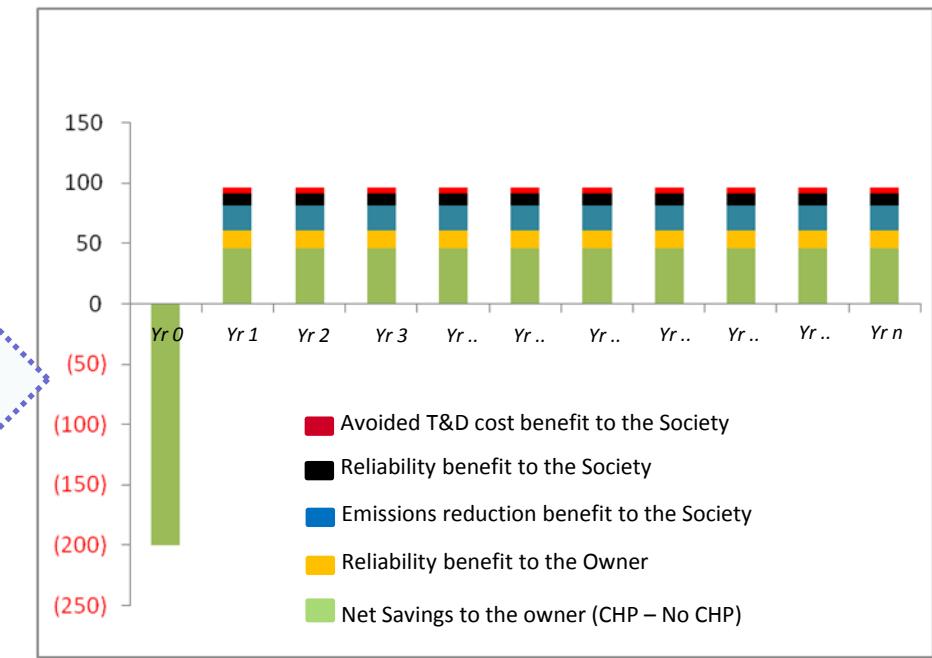
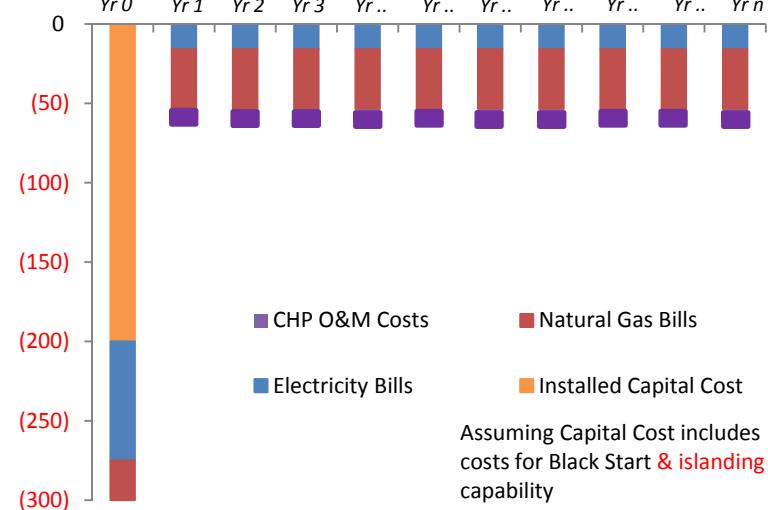
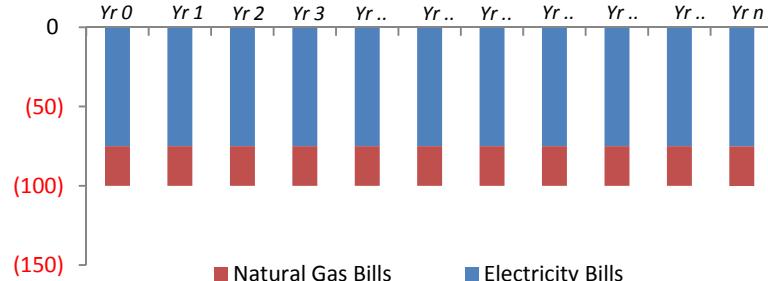
# Methodology for CBA – CHP Owner's perspective



1. NPV, B/C Ratio and IRR can be determined for the above net savings realized as a result of CHP installation
  2. Installed Capital Cost would account for incentives, if any, received by the CHP Owner
  3. Reliability benefits in part would depend upon the Owner's ability to realize benefits in case of a grid outage

*Graph not to scale; for illustrative purpose only*

# Methodology for CBA – Societal perspective



1. Installed Capital Cost would account for incentives, if any, received by the CHP Owner
  2. Reliability benefits in part would depend upon the Owner's ability to realize benefits in case of a grid outage

*Graph not to scale; for illustrative purpose only*

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# Financial assumptions requested for model spreadsheet

CHP Project Key Financial Assumptions	
Debt: Equity Ratio	?
Cost of Equity (%)	?
Cost of Debt (%)	?
Loan Repayment Period (yrs)	?
Depreciation Schedule	?
CHP Project Construction Period (days)	?

# NG and Electricity Tariff assumptions requested for model spreadsheet

1. CEEEP would like to meet with utility staff to understand ‘standby tariff’ for CHP users and future rates for consumers of electricity and natural gas

# User consumption data required for model spreadsheet

1. CEEEP would like to receive the following data for electricity and natural gas usage by a facility
  1. Monthly Peak
  2. Monthly Usage

# Reliability benefit calculation assumptions required for model spreadsheet

1. Capital Cost of Black Start equipment **& islanding costs** (\$/KW)
2. Private & Social assumption for Value of Loss Load (\$/MWh)
3. Outage frequency (no. of days/ year)

*Outage assumptions depend in part on the utility plans for grid hardening*

## Avoided costs assumptions for model spreadsheet

1. CEEEP is updating the avoided electricity, natural gas and environmental costs assumptions

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## NJ CHP – status of applications received

1. 1<sup>st</sup> round of Large Scale Combined Heat and Power – Fuel Cells (LSCHP-FC) Program (2012) – run by EDA with technical review by BPU
  - a. 6 projects approved (24.8 MW)
  - b. 2<sup>nd</sup> round initiated Jan 2013; 2 new applications received
2. ARRA solicitation Program (2010) - run by EDA with technical review by BPU
  - a. 6 projects approved (34 MW)
3. Small-scale CHP Program – run by TRC/BPU
4. We have received detailed applications for – 1.a (6 applications), 1.b (for 1 applicant), 2.a (6 applications), 3. (4 applications)
5. These applications were not part of a competitive solicitation process

*We are going through the received applications for CBA Analysis*

## SUMMARY OF WHAT HAS BEEN COMPLETED

1. A data base of 39 CHP technologies has been compiled using credible sources
2. A CBA model is being developed which would do the analysis of CHP from the perspective of owner and the society
3. Test cases are been run through the model
4. Stakeholders are been asked to provide input assumptions

*Stakeholders are requested to provide their inputs on assumptions within a period of 2 weeks from today*

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## Specific Next Steps

1. Comparison of stakeholder assumptions with information from received applications
2. Conduct CBA from an owner's and societal perspective for received applications and for generic projects

## Questions/Comments

Can be addressed to the below email ids

1. [ffelder@rutgers.edu](mailto:ffelder@rutgers.edu)
2. [rasika.athawale@rutgers.edu](mailto:rasika.athawale@rutgers.edu)

## References

1. PJM State of the Market – 2012, Section 2 – Energy Market, pg. 62
2. EPA – Air Emissions - <http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html> (last updated June 20, 2013)
3. EPA – Sources of Mercury Emissions in the US -  
<http://www.epa.gov/mats/powerplants.html>