Zero Energy Zoo Study
National Zoological Park, DC
Conservation Research Center, VA

Federal Facilities Council
National Academy of Sciences
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Basecase Energy Use and Cost

Name	Annual Electric Consumption (kWh)	Annual Natural Gas & Other Fuels Consumption (therms)	Annual Electric Cost ($)	Annual Natural Gas & Fuel Cost ($)
NZP and CRC Total	19,084,465	696770	$2,026,413	$1,005,438
Natl Zoological Park, DC	16,300,459	658,205	$1,902,493	$950,017
Cons. Res. Center, VA	2,784,006	38,565	$123,921	$55,421

Compliance Issues

- **The National Capital Planning Commission**
  - federal planning agency for the District of Columbia
  - staff of urban planners, architects, and landscape designers
  - provides overall planning guidance for federal land and buildings in the National Capital Region
  - reviews the design of federal projects
  - oversees long-range planning
  - monitors capital investment by federal agencies.
- **The National Environmental Policy Act (NEPA)**
  - decision making processes include environmental impacts and reasonable alternatives
  - Categorical exclusion; Finding of No Significant Impact; Environmental Assessment; Environmental Impact Statement
- **The National Energy Policy Act of 2005**
  - goal of reducing energy use by 2% per year until 2015
  - requires agencies to get at least 7.5 of their electricity from renewable energy (with on-site projects counting double toward the goal) by the year 2013
  - encourages public-private partnership by authorizing Energy Savings Performance Contracts,
- **Energy Independence and Security Act of 2007**
  - Zero Energy Buildings by 2030
  - Solar Hot Water in all new and renovated buildings.
- **National Historic Preservation Act of 1966**
  - requires a process (Section 106 Review) that involves input by a large number of stakeholders.
- [1] The National Capital Planning Commission: http://www.ncpc.gov/
- [2] The National Environmental Policy Act: http://www.epa.gov/compliance/nepa/index.html

Optimization

- Identify the cost combination of renewable energy technologies that:
  - Minimizes Life Cycle Cost
  - Achieves net zero energy use
    - "Net" means produces as much as consumed
      - Sum of NZP and CRC annual total
    - Uses utility system to
      - Store power under net metering policy
      - Buy power at retail rate when needed
      - Sell excess power at wholesale rate when available in excess of net metering policy

Renewable Energy Technologies Considered

- Photovoltaics (solar electricity)
- Wind Power
- Solar Ventilation Air Preheating
- Solar Water Heating
- Solar Thermal/Solar Thermal Electric
- Biomass Heat/Biomass Electric
- Daylighting

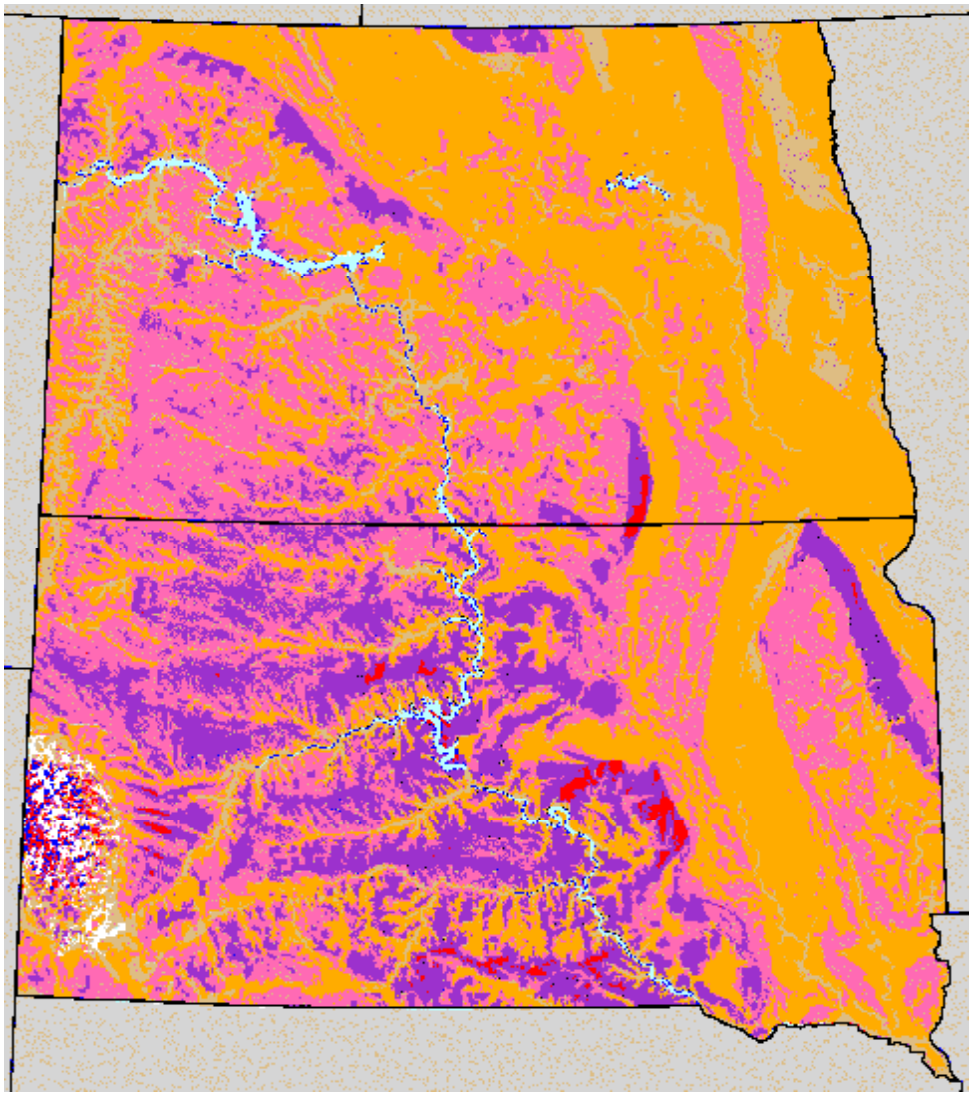
Best Mix of Renewable Energy Technologies Depends on:

- Renewable Energy Resources
- Technology Characterization
  - Cost ($/kW installed, O&M Cost)
  - Performance (efficiency)
- State, Utility and Federal Incentives
- Economic Parameters

Geographical Information System (GIS) Datasets

- NREL Datasets:
  - solar radiation 40x40 km grid
    - Horizontal, South-facing vertical, tilt=latitude
  - Wind Energy 200mx1000m grid
  - Biomass Resources
  - Illuminance for Daylighting
  - Temperature and Heating Degree Days
- Other Datasets
  - utility rates for each service territory from billing records (or Platts)
  - State and utility incentives and utility policy (from DSIRE)
  - Temperature and Heating Degree Day (NREL)
  - City Cost Adjustments (RS Means & Co)
- Location Independent
  - Installed Hardware Costs from NREL technology databook
  - Economic Parameters (discount rate, inflation rate)

Geographical Information System (GIS) Datasets



Wind Power

Selected Renewable Energy Resource Information (biomass breakdown and illuminance values also used)

Name	Heating Degree Days (65F)	Cooling Degree Days (65F)	Annual Average Solar tilt=lat (kWh/m2/day)	Annual Maximum Solar tilt=lat (kWh/m2/day)	Annual Average Solar horiz (kWh/m2/day)	Annual Average Wind Power Density (W/m2)	Annual Solar Vent Preheat Delivery (kWh/m2/yr)	Annual Direct Solar on E/W 1-axis tracker (kWh/m2/day)	Biomass, total residues within 50 miles (tons/year)
Natl Zoological Park, DC	3999	1503	4.69	5.70	4.01	121	419	2.9	1442000
Cons. Res. Center, VA	4763	1109	4.63	5.50	3.99	153	408	3.29	817000

Technology Characterizations

- Power Technologies Energy Data Book http://www.nrel.gov/analysis/power_databook
- Renewable Energy Technology Characterizations EPRI Topical Report No. TR-109496 http://www1.eere.energy.gov/ba/pba/tech_characterizations.html
- Project experience

Optimization Problem

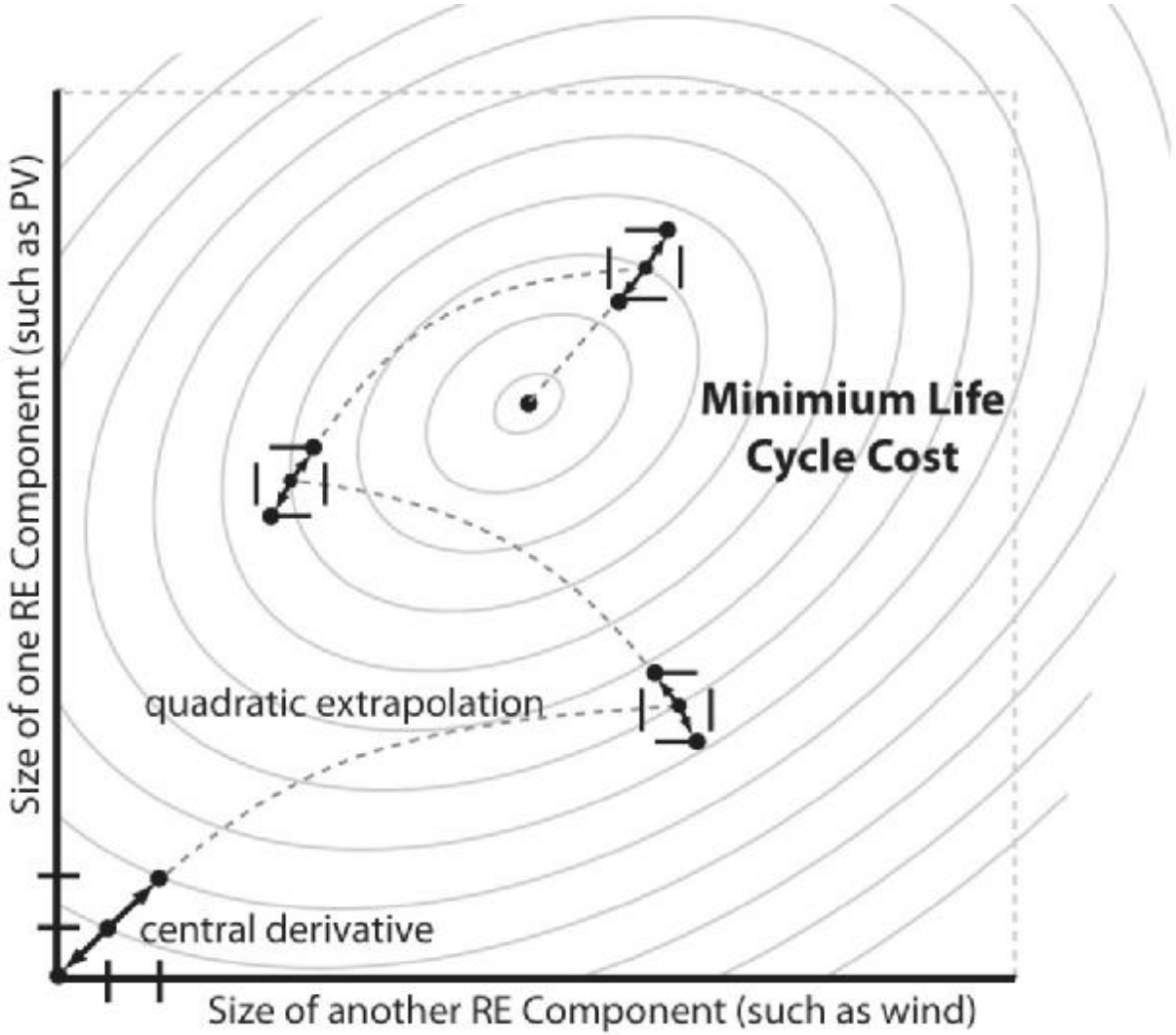
Objective: Minimize Life Cycle Cost ($)

Constraint: Sum of annual utility energy use equals ZERO
(gas and electric, NZP and CRC)

Microsoft Office Excel Spreadsheet function: SOLVER

- **Precision:** value of energy use 0.0 +/- 0.0001
- **Convergence:** change in life cycle cost less than $0.0001 for five iterations
- **Quadratic Extrapolation** to obtain initial estimates of the variables in one-dimensional search
- **Central Derivatives** used to estimate partial derivatives of the objective and constraint functions
- **Newtonian Search** Algorithm used at each iteration to determine the direction to search.

Optimization Technique



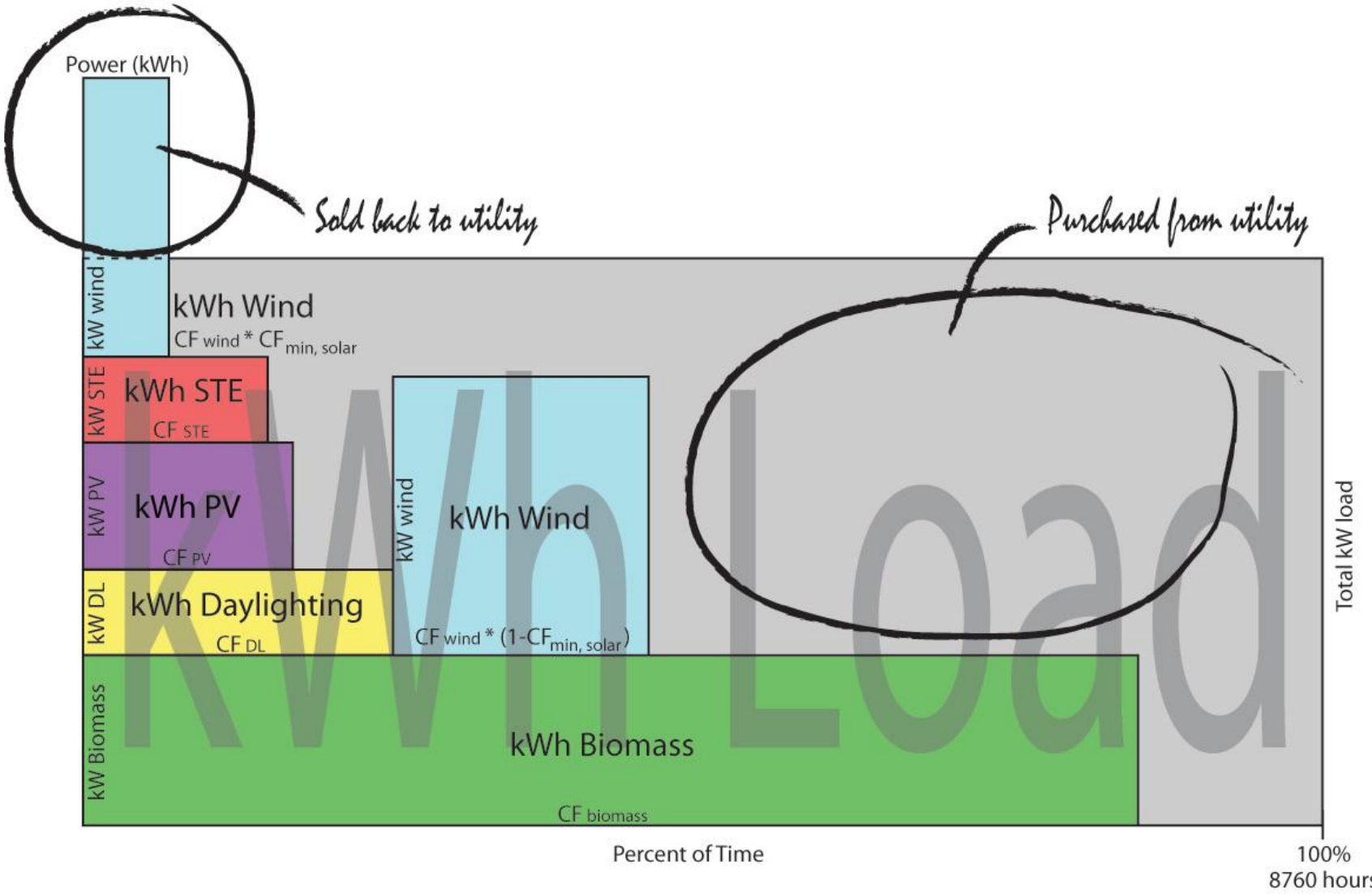
Economic Parameters

Discount Rate	4.6%
Fuel Escalation Rate	2.0%
Electric Escalation Rate	1.6%
Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis - April 2007, Annual Supplement to Handbook 135 http://www1.eere.energy.gov/femp/information/download_blcc.html	

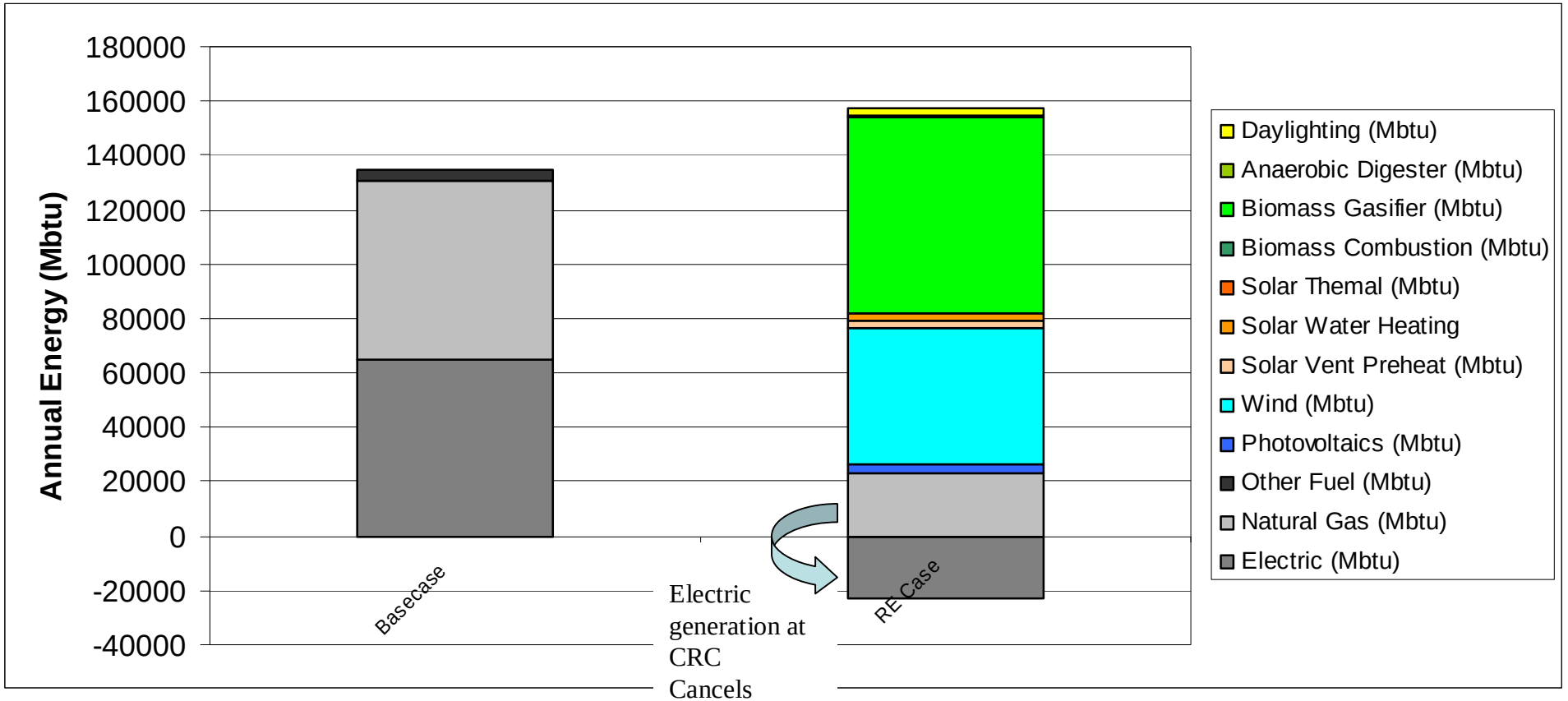
Results of Life Cycle Cost Optimization: Technology Sizes

	Photovoltaics Size (kW)	Wind Capacity (kW)	Solar Vent Preheat Area (ft2)	Solar Water Heating Area (ft2)	Biomass Gasifier Size (M Btu/h)	Biomass Cogeneration Size (kW)	Anaerobic Digester Size (FT3)	Anaerobic Digester Cogeneration Size (kW)	Daylight Aperture (Skylight) Area (ft2)
Natl. Zoological Park, DC	638	0	10655	7,535	10.996	1,168	3,723	12	21221
Cons. Res. Cntr., VA	224	14,500	8,075	2,180	0.000	0	459	0	6476
Total	862	14,500	18,730	9,715	10.996	1,168	4,182	12	27697

How technologies act together (Dispatch Algorithm)



Annual Energy from Each Technology (with Basecase)

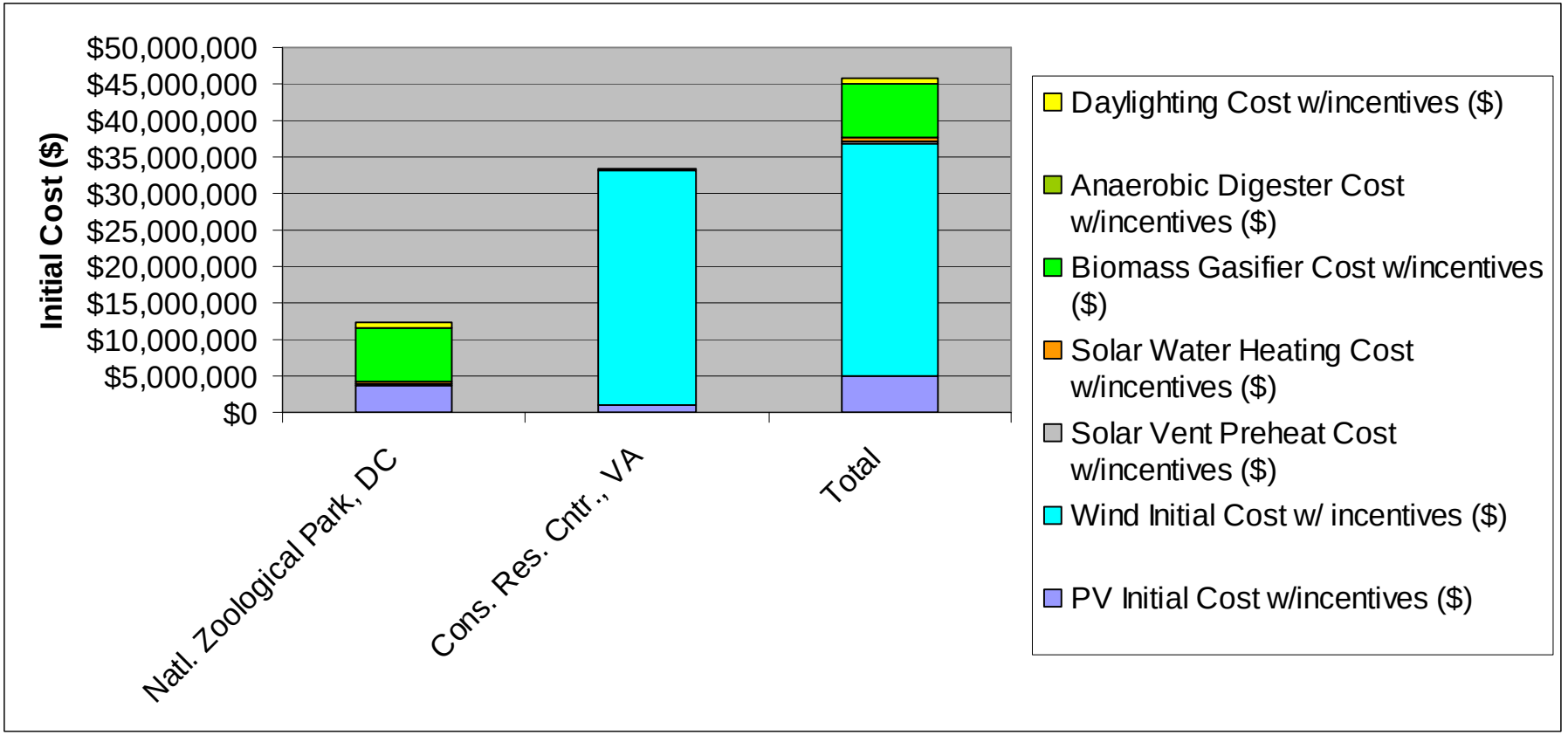


Electric generation at CRC Cancels remaining gas use at NZP

Initial Costs for Each Technology

	PV Initial Cost w/incentives ($)	Wind Initial Cost w/ incentives ($)	Solar Vent Preheat Cost w/incentives ($)	Solar Water Heating Cost w/incentives ($)	Biomass Gasifier Cost w/incentives ($)	Anaerobic Digester Cost w/incentives ($)	Daylighting Cost w/incentives ($)	Total Initial Cost ($)
Natl. Zoological Park, DC	$3,780,188	$0	$149,171	$385,039	$7,288,563	$77,480	$682,038	$12,362,478
Cons. Res. Cntr., VA	$1,156,690	$31,900,000	$113,044	$111,398	$0	$6,698	$208,113	$33,495,943
Total	$4,936,878	$31,900,000	$262,215	$496,437	$7,288,563	$84,178	$890,150	$45,858,421

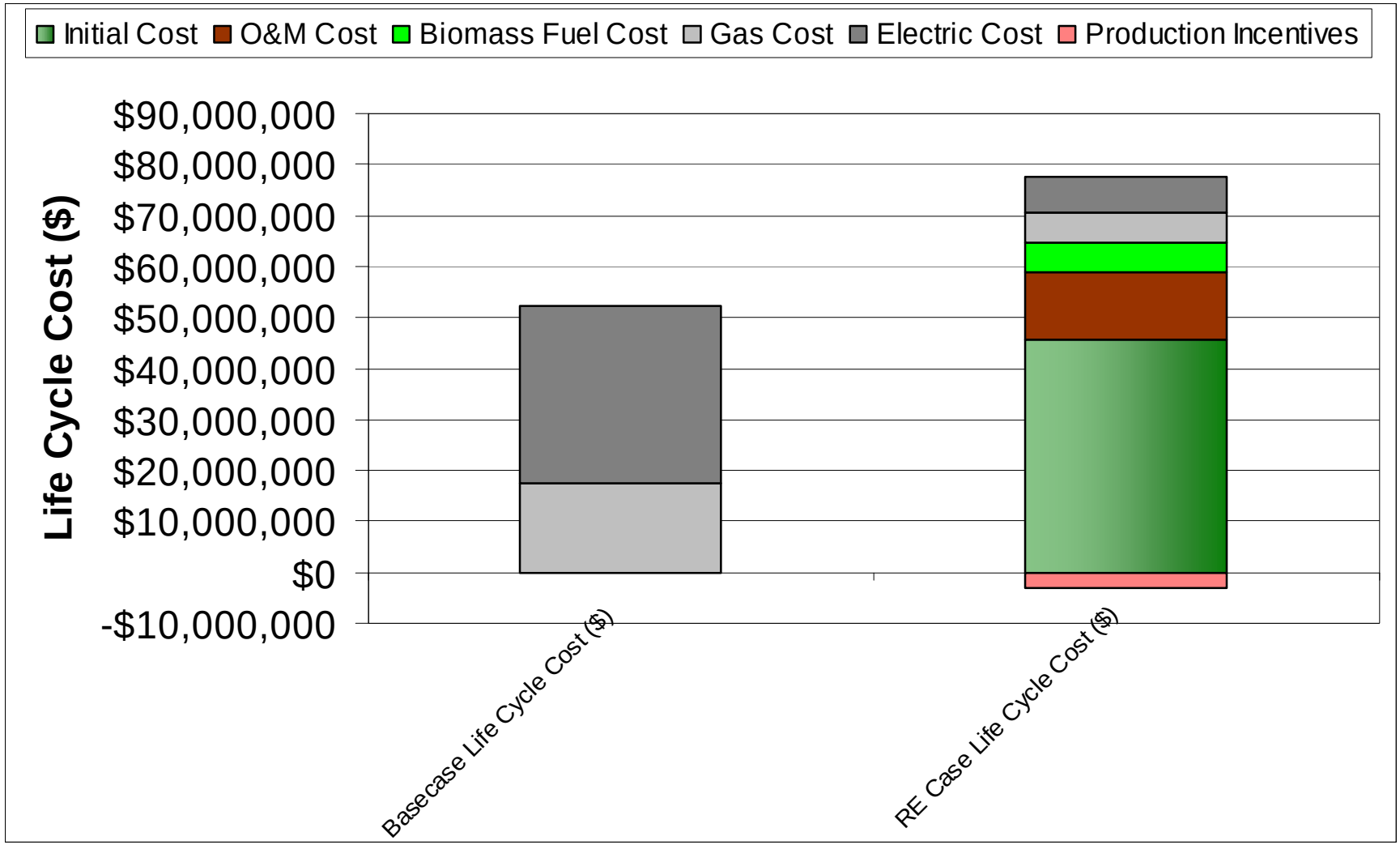
Initial Costs for Each Technology



Life Cycle Cost of Zero Energy Case versus BaseCase

Name	Basecase Life Cycle Cost ($)	RE Case Life Cycle Cost ($)
Initial Cost	$0	$45,858,421
O&M Cost	$0	$13,135,266
Biomass Fuel Cost	$0	$5,762,545
Gas Cost	$17,323,188	$5,713,053
Electric Cost	$34,914,085	$7,196,488
Production Incentives	$0	-$2,887,806
Total	**$52,237,272**	**$74,777,968**

Life Cycle Cost of Zero Energy Case versus BaseCase



Concerns regarding truck traffic at NZP and alternatives

Table 1. Comparison of Alternatives for Biomass Energy at NZP

Alternative	Biomass Fuel Delivered to NZP	Bio-oil delivered to NZP	Extra wind generation at CRC to compensate for gas use at NZP
Details	Wood Fuel for heat and power at NZP, 11000 tons/year at $40/ton, 550 trucks/year, new on-site bulk storage, 14.5 MW wind at CRC for electric,	Biodiesel for heat and power at NZP, 865 kgal/year at $3/gal, 91 trucks/year, use existing on-site storage, low capital cost, high annual fuel cost, 14.5 MW wind at CRC for electric,	Wind at CRC to compensate for gas use at NZP, 33 MW wind at CRC, could be 22 large 1.5 MW turbines, each 200ft in diameter, only on-site waste biomass used at NZP, no truck deliveries,
Life Cycle Cost	$74 million	$103 million	$110 Million,.

Photovoltaics

Technology Characteristics
Photovoltaics

Initial Cost	$8,730.00	$/kW	RS Means Green Building Project Planning and Cost Estimating, 2006
O$M	0.006	$/kWh	Renewable Energy Technology Characterizations, EPRI TR-109496, 1997.C185
BOS Efficiency	0.77		PVWatts documentation www.nrel.gov

Photovoltaics NZP buildings identified during site visit

Name	Photovoltaics Size (kW)	PV Initial Cost w/incentives ($)	PV Annual Energy Delivery (kWh/year)	Capacity Factor ()	PV Annual Utility Cost Savings ($)	PV Annual O&M Cost ($/year)	PV Payback Period (years)
Education & Administration Build	18	$68,458	19280	12.2%	$2,250	$116	32.1
Panda Cafe	5	$18,608	5511	12.6%	$643	$33	30.5
Panda Plaza Rest Rooms	4	$23,686	4708	13.4%	$549	$28	45.4
Panda Plaza	10	$59,216	11666	13.3%	$1,362	$70	45.8
Elephant House	49	$290,156	52850	12.3%	$6,168	$317	49.6
Reptile Discovery Center	14	$82,902	14856	12.1%	$1,734	$89	50.4
Police Station/Rest Rooms	14	$82,902	17096	13.9%	$1,995	$103	43.8
Amazonia	12	$71,059	12511	11.9%	$1,460	$75	51.3
Amazonia Filtration	24	$142,117	26161	12.4%	$3,053	$157	49.1
Lion/Tiger Kiosk	6	$35,529	7293	13.9%	$851	$44	44.0
Bird House	16	$94,745	17883	12.8%	$2,087	$107	47.9
Conservation Biology-Animal Re	104	$615,842	112976	12.4%	$19,203	$678	33.2
Conservation Biology - Animal Bi	32	$189,490	34881	12.4%	$4,071	$209	49.1
Veterinary Hospital	35	$207,255	40145	13.1%	$4,685	$241	46.6
Necropsy	22	$130,274	23981	12.4%	$2,799	$144	49.1
Main Barn	28	$165,804	29295	11.9%	$3,419	$176	51.1
Sloth Bear	6	$35,529	7156	13.6%	$835	$43	44.8
Panda Overlook	25	$147,584	27067	12.4%	$3,159	$162	49.2
Panda West	15	$87,847	16111	12.4%	$1,880	$97	49.2
Parking Lot C	136	$803,075	147282	12.4%	$6,264	$884	149.3
Parking Lot B	64	$378,980	76719	13.7%	$8,954	$460	44.6
Natl Zoological Park, DC	**638**	**$3,731,058**	**705430**	**12.6%**	**$77,424**	**$4,233**	**51.0**


ST#2
PV#5
PV#22
PV#21
ST#1
ST#6
ST#7
PV#19
PV12
PV#8
ST#8
PV16
PV#15

Photovoltaics
CRC buildings identified during site visit

Name	Photovoltaics Size (kW)	PV Initial Cost w/incentives ($)	PV Annual Energy Delivery (kWh/year)	Capacity Factor ()	PV Annual Utility Cost Savings ($)	PV Annual O&M Cost ($/year)	PV Payback Period (years)
Maintenance and Research Offic	56	$289,173	68523	14.0%	$3,050	$411	109.6
Breeding Barn	25	$129,095	29567	13.5%	$1,316	$177	113.4
Veterinary Hospital	23	$118,767	27859	13.8%	$1,240	$167	110.7
Vehicle Repair Shop	17	$87,785	20245	13.6%	$901	$121	112.6
Carpenter Shop	18	$92,948	21284	13.5%	$947	$128	113.4
Small Animal Facility	43	$222,043	45972	12.2%	$2,046	$276	125.4
Rivinus Barn	33	$170,405	35666	12.3%	$1,588	$214	124.1
Rivinus Annex	9	$46,474	9673	12.3%	$431	$58	124.8
Cons. Res. Center, VA	**224**	**$1,156,690**	**258789**	**13.2%**	**$11,519**	**$1,553**	**116.1**

Wind Power

Technology Characteristics
Wind Power

Wind Turbine Efficiency	35%	
Capital Cost	$926	$/m2 swept area
O&M Cost	7.9	$/year/kW
Power/Area	0.46	kW/m2
Capital Cost	2000	$/kW

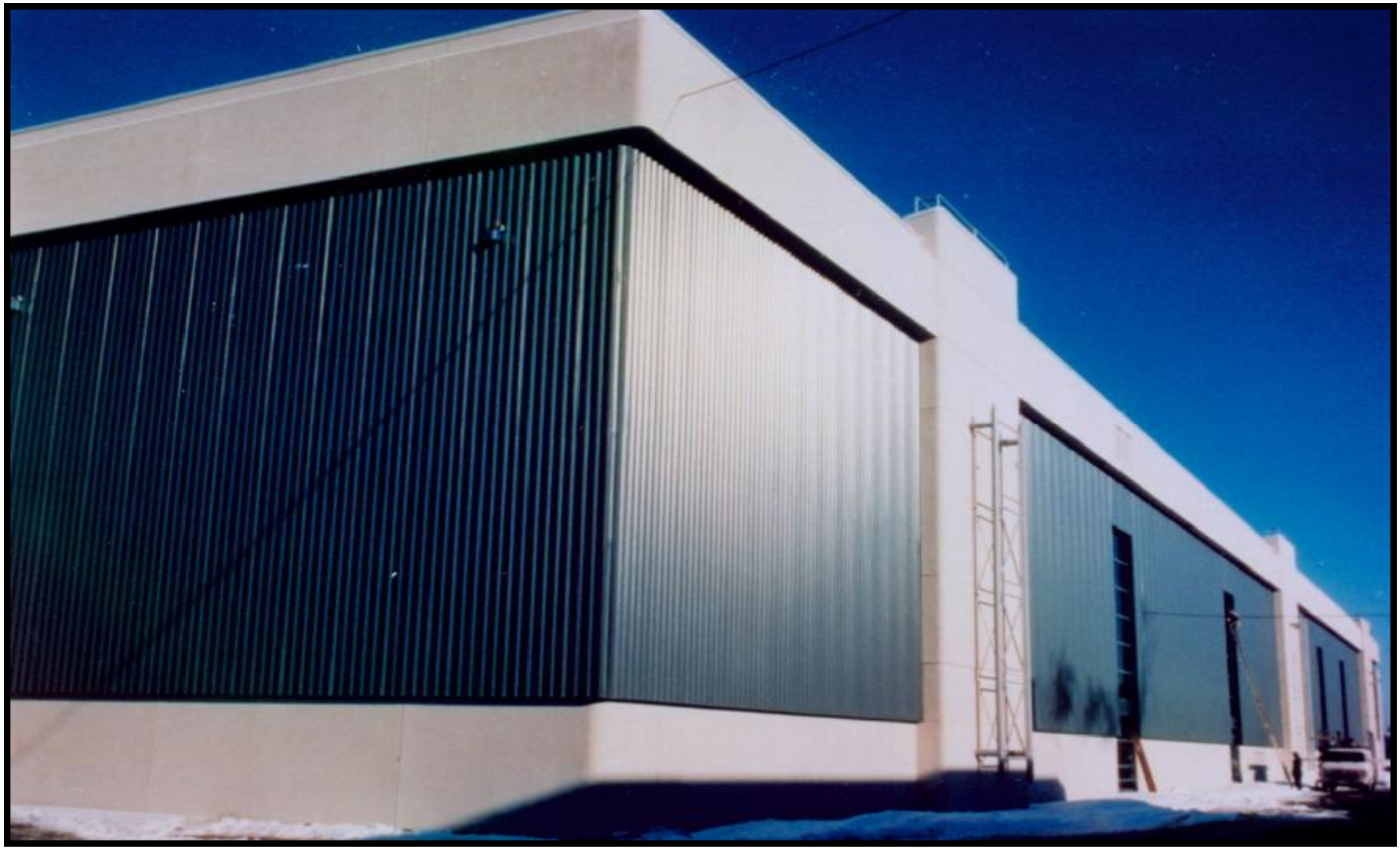
http://www.eia.doe.gov/cneaf/solar.renewables/rea_issues/wind.html

http://www.pge.com/suppliers_purchasing/new_generator/incentive/avail

Wind Energy

Name	Wind Turbine Swept Area (m2)	Wind Capacity (kW)	Wind Initial Cost w/ incentives ($)	Wind Net Metering up to (kW)	Avoided Cost ($/kwh)	Wind Annual Energy Delivery (kWh/year)	Capacity Factor (%)	Wind Annual Cost Savings ($)	Wind Annual O&M Cost ($/year)	Wind Payback Period (years)
Natl Zoological Park, DC	0	0	$0	100	0.03	0	0.00%	$0	$0	na
Cons. Res. Center, VA	31,306	14,500	$31,900,000	100	0.03	14,685,758	11.56%	$684,939	$114,550	55.9

Solar Ventilation Air Preheat



Bombardier Inc., Canada

Technology Characterization
Solar Ventilation Air Preheat

Initial Cost	20	$/sf
O&M Cost	0	
Ventilation Rate (cfm/sf)	0.12	0.12

Solar Ventilation Air Preheating
NZP buildings identified during site visit

Name	Solar Vent Preheat Area (ft2)	Annual Gas Savings (therms/year)	Initial Cost ($)	Annual Utility Cost Savings ($/year)	Solar Vent Preheat Cost w/incentives ($)	Solar Vent Preheat Payback Period (years)
Elephant House	1,239	2,058	$24,784	$2,971	$17,349	5.8
Small Mammal House	898	1,491	$22,344	$2,153	$15,641	7.3
Police Station/Rest Rooms	287	476	$5,736	$687	$4,015	5.8
Mane Restaurant	534	887	$10,685	$1,281	$7,479	5.8
Amazonia	1,277	2,122	$25,548	$3,062	$17,884	5.8
Amazonia Filtration	300	498	$6,001	$719	$4,200	5.8
Valley Rest Rooms	30	50	$606	$73	$424	5.8
General Services Building	4,878	8,101	$97,551	$11,692	$68,286	5.8
Boiler Plant	157	261	$3,146	$377	$2,202	5.8
Propagation Building	491	815	$9,816	$1,176	$6,871	5.8
Hazmat Storage	10	16	$193	$23	$135	5.8
Necropsy	59	99	$1,189	$143	$832	5.8
Quarantine	126	208	$2,511	$301	$1,757	5.8
Main Barn	137	227	$2,736	$328	$1,915	5.8
Chicken House	13	21	$257	$31	$180	5.8
Natl Zoological Park, DC	**10,655**	**17,332**	**$213,101**	**$25,016**	**$149,171**	**6.0**

CRC Solar Ventilation Air Preheating

Name	Solar Vent Preheat Area (ft2)	Annual Gas Savings (therms/year)	Initial Cost ($)	Annual Utility Cost Savings ($/year)	Solar Vent Preheat Cost w/incentives ($)	Solar Vent Preheat Payback Period (years)
GIS Computer Lab	100	162	$2,006	$233	$1,404	6.0
Fire Station	34	54	$670	$78	$469	6.0
Grounds Maintenance Building	115	186	$2,296	$267	$1,607	6.0
Fence Crew Shop	102	164	$2,030	$236	$1,421	6.0
Administration Building	262	424	$5,245	$610	$3,672	6.0
Training/Conference Center	435	703	$8,698	$1,011	$6,089	6.0
Paint Shop	18	29	$362	$42	$253	6.0
Mule Barn	329	532	$6,575	$764	$4,602	6.0
Maintenance and Research Offic	116	188	$2,325	$270	$1,628	6.0
Animal Buildings 3&4	778	1,258	$15,560	$1,808	$10,892	6.0
Commissary and Supply	150	243	$3,002	$349	$2,102	6.0
Lower Wolf Facility	46	75	$927	$108	$649	6.0
Breeding Barn	54	88	$1,086	$126	$760	6.0
Waste Water Treatment Building	14	23	$279	$32	$195	6.0
Church Barn	346	560	$6,924	$805	$4,847	6.0
Animal Supply	45	73	$900	$105	$630	6.0
Horse Barn	86	139	$1,713	$199	$1,199	6.0
Animal Buildings 1&2	794	1,284	$15,874	$1,845	$11,112	6.0
Dormitory	113	182	$2,250	$261	$1,575	6.0
Auditorium	183	296	$3,659	$425	$2,561	6.0
Research Office and Private Res	49	80	$989	$115	$692	6.0
Laundry/Office	21	34	$425	$49	$298	6.0
Veterinary Hospital	417	675	$8,348	$970	$5,844	6.0
Office Annex	342	552	$6,831	$794	$4,782	6.0
Vehicle Repair Shop	74	120	$1,483	$172	$1,038	6.0
Boiler Room/Mason Shop	14	23	$283	$33	$198	6.0
Carpenter Shop	92	148	$1,830	$213	$1,281	6.0
Small Animal Facility	1,103	1,784	$22,067	$2,564	$15,447	6.0
Leach House	185	299	$3,694	$429	$2,586	6.0
Green Hill Barn	279	451	$5,572	$648	$3,901	6.0
Slate Hill Barn	338	547	$6,767	$786	$4,737	6.0
Rivinus Barn	267	431	$5,334	$620	$3,734	6.0
Rivinus Annex	101	163	$2,016	$234	$1,411	6.0
Meade Barn	338	546	$6,755	$785	$4,728	6.0
Waller Barn	330	533	$6,594	$766	$4,615	6.0
Cons. Res. Center, VA	**8,069**	**13,049**	**$161,372**	**$18,752**	**$112,960**	**6.0**

Solar Water Heating

Technology Characterization
Solar Water Heating

Hot Water as Fraction of Total Building Energy		
Office	0.089506	
Education	0.21942	
Health Care	0.262063	
lodging	0.403771	
public assembly	0.153914	
food service	0.112016	
food sales	0.042623	
warehouse	0.052219	
other 15.3	0.08885	
all	0.152486	

source: DOE/OBT Energy Databook

SDHW Efficiency	0.4	
Cost	73	$/sf
O&M Cost	0.005	% of initial cost
Aux efficiency	0.8	

Solar Water Heating
NZP buildings identified during site visit

Name	Solar Water Heating Area (ft2)	Solar Water Heatingl Initial Cost ($)	Solar Water Heating Gas Savings (therms/year)	Solar Water Heating Annual Utility Cost Savings ($/year)	Solar Water Heating Cost w/incentives ($)	Solar Water Heating O&M Cost ($/year)	Solar Water Heating Payback Period (years)
Education & Administration Build	120	$8,760	325	$470	$6,132	$44	14.4
Panda Cafe	120	$8,760	325	$470	$6,132	$44	14.4
Panda Plaza Rest Rooms	413	$30,149	1,120	$1,617	$21,104	$151	14.4
Panda Plaza	450	$32,850	1,220	$1,761	$22,995	$164	14.4
Elephant House	322	$23,506	873	$1,260	$16,454	$118	14.4
Small Mammal House	300	$21,900	814	$1,174	$15,330	$110	14.4
Great Ape House	300	$21,900	814	$1,174	$15,330	$110	14.4
Police Station/Rest Rooms	400	$29,200	1,085	$1,566	$20,440	$146	14.4
Mane Restaurant	760	$55,480	2,061	$2,975	$38,836	$277	14.4
Amazonia	1,800	$131,400	4,881	$7,046	$91,980	$657	14.4
Amazonia Filtration	400	$29,200	1,085	$1,566	$20,440	$146	14.4
Bird House	400	$29,200	1,085	$1,566	$20,440	$146	14.4
General Services Building	600	$43,800	1,627	$2,349	$30,660	$219	14.4
Veterinary Hospital	1,150	$83,950	3,119	$4,501	$58,765	$420	14.4
Natl Zoological Park, DC	**7,535**	**$550,055**	**20,434**	**$29,493**	**$385,039**	**$2,750**	**14.4**

CRC Solar Water Heating

Name	Solar Water Heating Area (ft2)	Solar Water Heatingl Initial Cost ($)	Solar Water Heating Gas Savings (therms/year)	Solar Water Heating Annual Utility Cost Savings ($/year)	Solar Water Heating Cost w/incentives ($)	Solar Water Heating O&M Cost ($/year)	Solar Water Heating Payback Period (years)
Visitor Cottage	80	$5,840	64	$93	$4,088	$29	64.5
Private Residence 0025	80	$5,840	214	$308	$4,088	$29	14.7
Private Residence 0040	80	$5,840	214	$308	$4,088	$29	14.7
Private Residence 0054	80	$5,840	155	$223	$4,088	$29	21.1
Private Residence 0056	80	$5,840	155	$223	$4,088	$29	21.1
Private Residence 0082	80	$5,840	166	$239	$4,088	$29	19.5
Private Residence 0098	80	$5,840	214	$308	$4,088	$29	14.7
Private Residence 0110	80	$5,840	214	$308	$4,088	$29	14.7
Private Residence 0111	80	$5,840	214	$308	$4,088	$29	14.7
Private Residence 0115	80	$5,840	133	$191	$4,088	$29	25.3
Animal Buildings 3&4	300	$21,900	803	$1,154	$15,330	$110	14.7
Private Residence 0142	80	$5,840	214	$308	$4,088	$29	14.7
Private Residence 0175	80	$5,840	164	$235	$4,088	$29	19.8
Research Office and Private Res	80	$5,840	166	$238	$4,088	$29	19.6
Laundry/Office	120	$8,760	71	$102	$6,132	$44	104.8
Private Residence 0740	80	$5,840	214	$308	$4,088	$29	14.7
Private Residence 0860	80	$5,840	214	$308	$4,088	$29	14.7
Private Residence 1016	80	$5,840	214	$308	$4,088	$29	14.7
Private Residence 1154	80	$5,840	214	$308	$4,088	$29	14.7
Private Residence 1180	80	$5,840	214	$308	$4,088	$29	14.7
Private Residence 2518	80	$5,840	113	$163	$4,088	$29	30.5
Private Residence 7400	80	$5,840	156	$224	$4,088	$29	20.9
Private Residence 7600	80	$5,840	156	$224	$4,088	$29	21.0
Cons. Res. Center, VA	**2,180**	**$159,140**	**4,660**	**$6,696**	**$111,398**	**$796**	**18.9**

Solar Thermal/Solar Thermal Electric

Technology Characterization
Solar Thermal/Solar Thermal Electric

Solar Thermal cost	50	$/sf	
O&M cost	$0.127	$/therm/year	
Efficiency	0.33		
Cost of thermal storage	$1,465	$/therm	http://www.nrel.gov/csp/troughnet/pdfs/3516.pdf
Hours per day of solar collection	6		
Cogen Cost	1650	$/kW	
cogen Efficiency	0.3		
Boiler Capacity Factor	0.85		
Hx effectiveness	0.7		
Federal Production tax credit	0.01	$/kwh	

Name	Annual Direct Solar on E/W 1-axis tracker (kWh/m2/day)
Natl Zoological Park, DC	**2.9**
Cons. Res. Center, VA	**3.29**

Solar Thermal/Solar Thermal Electric …found not to be cost effective

Solar Thermal Area (ft2)	Solar Thermal Cogeneration Size (kW)	Solar Thermal Gas Savings (therms/year)	Solar Thermal Electric Delivery (kWh/year)	Solar Thermal Annual Utility Cost Savings ($/year)	Solar Thermal Cost w/incentives ($)	Solar Thermal O&M Cost ($/year)	Solar Thermal Payback Period (years)
0	0	0	0	0	$0	$0	#DIV/0!

Biomass Energy

Biomass – Technologies

Combustion Platform

Combustion of biomass to generate steam, and topping cycle for steam co-generation of heat and power

Gasification Platform

1A biomass gasification with syngas utilization via conventional steam cycle

1B biomass gasification with syngas utilization via spark-ignition reciprocating engines

1C biomass gasification with syngas utilization via combustion turbine combined cycle

Pyrolysis Platform

2A biomass fast pyrolysis with bio-oil utilization via conventional steam cycle

2B biomass fast pyrolysis with bio-oil utilization via compression-ignition reciprocating
engines

2C biomass fast pyrolysis with bio-oil utilization via combustion turbine combined cycle

Anaerobic Digestion Platform

3A AD of biomass with biogas utilization via spark-ignition reciprocating engines

3B AD of biomass with biogas utilization via micro-turbine

3C AD of biomass with biogas utilization via molten carbonate fuel cell

Technology Characterization
Biomass Energy

Biomass heating value	100	therms/ton
Boiler Cost	500000	$/MBH
Cogen Cost	1650	$/kW
Fuel Storage and Handling	250000	$/MBH
Boiler Efficiency	0.75	
cogen Efficiency	0.3	
Boiler Capacity Factor	0.85	
Hx effectiveness	0.7	
fixed cost per ton	20	
trucking cost	1	$/sq mile/ton
Federal Production tax credit	0.01	$/kwh
Biomass O&M Cost	15000	$/yr/Mmbtuh
http://www.eia.doe.gov/oiaf/analysispaper/biomass/index.html		

Biomass Energy

Gasification of On-site solid dry waste

Biomass Initial Cost ($)	Biomass Natural Gas Savings (therms/year)	Biomass Gasifier Electric Delivery (kWh/year)	Biomass Gasifier Capacity Factor	Biomass Gasifier Annual Utility Cost Savings ($/year)	Tons of Fuel Used	per ton fuel cost ($/ton)	Fuel Cost ($)	Avoided Disposal Cost ($)	Biomass Gasifier Cost w/incentives ($)	Biomass Gasifier O&M Cost($/year)	Biomass Gasifier Payback Period (years)
$7,288,563	420,952	8,696,928	85.0%	$1,787,874	10,917	$33.28	$334,458	$42,077	$7,288,563	$632,453	8.4
$0	0	0	0.0%	$0	0	$20.20	$0	$0	$0	$0	#DIV/0!

Biomass Energy

Anaerobic digestion of on-site wet manure waste.

Name	Anaerobic Digester Size (FT3)	Anaerobic Digester Cogeneration Size (kW)	Anaerobic Digester BioGas Delivery (therms/year)	Anaerobic Digester Initial Cost ($)	Anaerobic Digester Natural Gas Savings (therms/year)	Anaerobic Digester Electric Delivery (kWh/year)	Anaerobic Digester Capacity Factor	Anaerobic Digester Annual Utility Cost Savings ($/year)	Anaerobic Digester Tons of Fuel Used
Natl Zoological Park, DC	3,723	12	7,364	$77,480	2,872	75,538	71.9%	$16,868	1,624
Cons. Res. Center, VA	459	0.000	890	$6,698	890	0	0.0%	$1,279	200

Air Quality Concerns

Fuel	CO2 emissions (kg/TJ)	N2O emissions (kg/TJ)
Natural Gas	56,100	0.1
Wood	112,000	4.0
Bio-diesel	70,800	0.6
Bio-gas	54,600	0.1

TJ= trillion joules,
2006 IPCC Guidelines for National Greenhouse Gas Inventories
Volume 2 : Energy
TABLE 2.2 DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN THE ENERGY INDUSTRIES
(kg of greenhouse gas per TJ on a Net Calorific Basis)
http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

Daylighting

Technology Characterizations
Daylighting

	Lighting levels	
Office	30	fc
Warehouse	15	fc
Utility	30	fc
skylight transmittance	0.7	
lightwell transmittance	0.5	
Coefficient of Utilizatio	0.55	
Coefficient of Utilizatio	0.45	
Luminous Efficacy Ele	100	lumens/wat
Roof U-value	0.1	btu/hr/F
Skylight Uvalue	0.5	btu/hr/F
Cooling COP	3.5	
Heating Efficiency	0.8	
Skylight Cost	25	$/sf
Controls cost	0.25	$/sf floor ar

Daylighting NZP buildings

Name	Total Skylight Area (ft2)	Annual Electric Savings (kWh/year)	Annual Natural Gas Savings (therms/year)	Daylighting Cost w/incentives ($)	Daylighting Annual Cost Savings ($/year)	Daylighting Payback Period (years)
Education & Administration Build	1,666.0	74,266.4	(1,000.8)	$53,542	$7,223	7.4
Cheetah Conservation Station	2,833.8	126,327.7	(1,702.3)	$91,075	$12,287	7.4
Panda House	309.7	13,807.8	(186.1)	$9,955	$1,343	7.4
Panda Cafe	32.0	1,427.1	(19.2)	$1,029	$139	7.4
Panda Plaza Rest Rooms	59.5	2,650.5	(35.7)	$1,911	$258	7.4
Panda Plaza	121.2	5,402.2	(72.8)	$3,895	$525	7.4
Elephant House	1,157.3	51,589.1	(695.2)	$37,193	$5,018	7.4
Mongolian Horses	558.2	24,885.9	(335.4)	$17,941	$2,421	7.4
Peccaries	16.9	753.5	(10.2)	$543	$73	7.4
Small Mammal House	1,043.3	46,510.0	(626.7)	$33,531	$4,524	7.4
Great Ape House	1,171.3	52,214.2	(703.6)	$37,644	$5,079	7.4
Gibbon Ridge	36.4	1,621.8	(21.9)	$1,169	$158	7.4
Reptile Discovery Center	1,368.0	60,983.9	(821.8)	$43,966	$5,932	7.4
Think Tank	897.0	39,988.3	(538.9)	$28,829	$3,889	7.4
Gibbon Shop	27.4	1,220.5	(16.4)	$880	$119	7.4
Police Station/Rest Rooms	267.8	11,939.1	(160.9)	$8,607	$1,161	7.4
Mane Restaurant	498.9	22,240.5	(299.7)	$16,034	$2,163	7.4
Amazonia	1,192.9	53,179.0	(716.6)	$38,339	$5,172	7.4
Amazonia Filtration	280.2	12,490.3	(168.3)	$9,005	$1,215	7.4
Valley Rest Rooms	28.3	1,261.0	(17.0)	$909	$123	7.4
Bird House	1,383.3	61,664.6	(831.0)	$44,457	$5,998	7.4
General Services Building	4,555.0	203,057.0	(2,736.3)	$146,393	$19,750	7.4
Boiler Plant	146.9	6,548.3	(88.2)	$4,721	$637	7.4
Propagation Building	458.3	20,431.4	(275.3)	$14,730	$1,987	7.4
Veterinary Hospital	616.0	27,461.1	(370.1)	$19,798	$2,671	7.4
Necropsy	55.5	2,475.2	(33.4)	$1,784	$241	7.4
Quarantine	117.2	5,225.7	(70.4)	$3,767	$508	7.4
Main Barn	127.8	5,695.8	(76.8)	$4,106	$554	7.4
Chicken House	12.0	534.1	(7.2)	$385	$52	7.4
Sloth Bear	171.5	7,645.8	(103.0)	$5,512	$744	7.4
Panda Support Building	13.3	593.2	(8.0)	$428	$58	7.4
Natl Zoological Park, DC	**21,222.9**	**946,091.1**	**(12,749.0)**	**$682,078**	**$92,021**	**7.4**

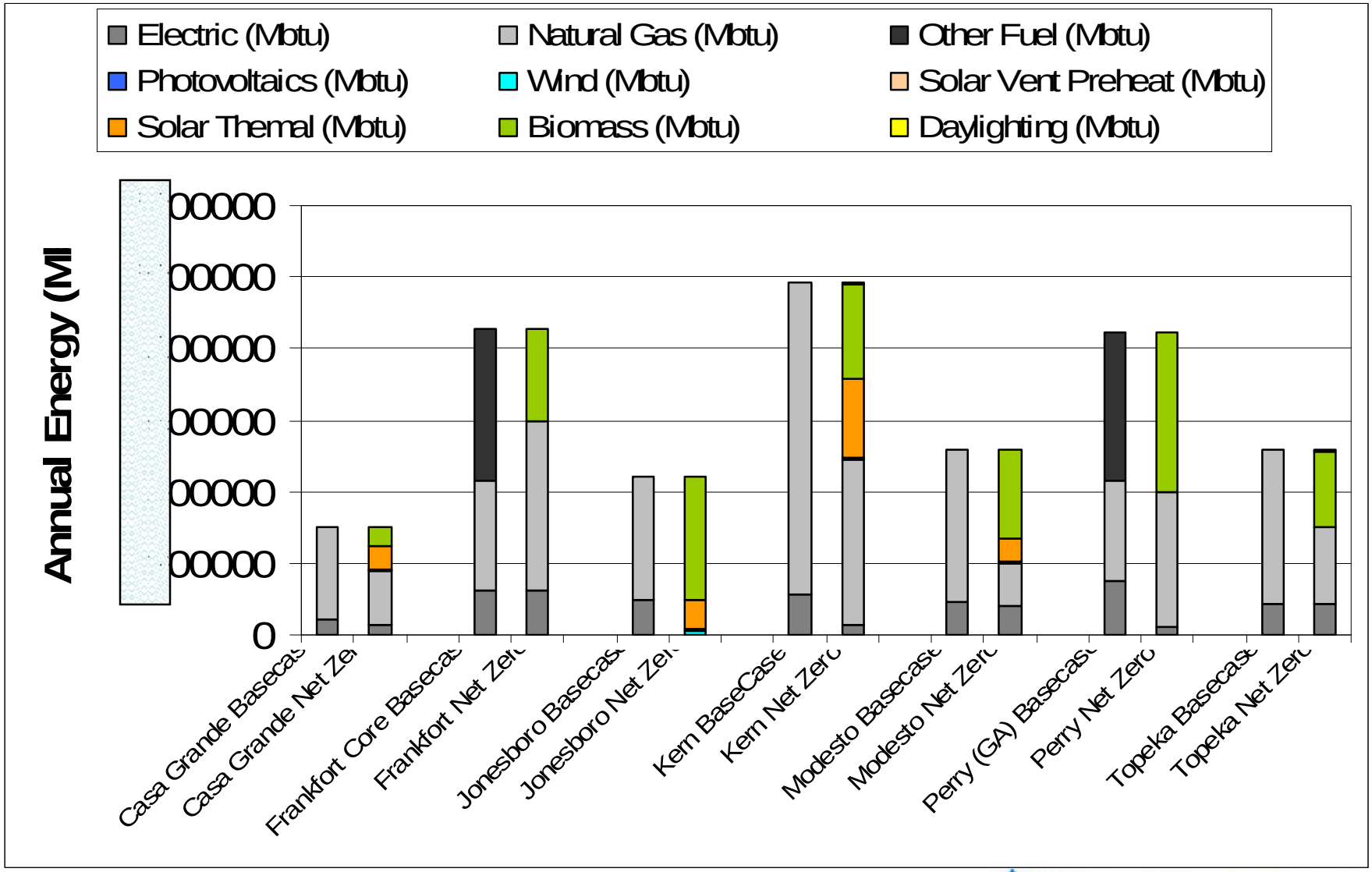
CRC Daylighting

Name	Total Skylight Area (ft2)	Annual Electric Savings (kWh/year)	Annual Natural Gas Savings (therms/year)	Daylighting Cost w/incentives ($)	Daylighting Annual Cost Savings ($/year)	Daylighting Payback Period (years)
GIS Computer Lab	93.7	4,240.3	(45.4)	$3,011	$123	24.4
Fire Station	31.3	1,416.9	(15.2)	$1,006	$41	24.4
Grounds Maintenance Building	107.2	4,852.7	(52.0)	$3,446	$141	24.4
Administration Building	244.9	11,086.6	(118.7)	$7,872	$323	24.4
Training/Conference Center	406.2	18,384.3	(196.9)	$13,053	$535	24.4
Paint Shop	16.9	764.0	(8.2)	$542	$22	24.4
Butler Building	51.8	2,346.5	(25.1)	$1,666	$68	24.4
Maintenance and Research Offic	108.6	4,914.2	(52.6)	$3,489	$143	24.4
Commissary and Supply	140.2	6,345.6	(67.9)	$4,506	$185	24.4
Breeding Barn	50.7	2,294.8	(24.6)	$1,629	$67	24.4
Waste Water Treatment Building	13.0	589.9	(6.3)	$419	$17	24.4
Church Barn	323.3	14,634.4	(156.7)	$10,391	$426	24.4
Horse Barn	80.0	3,621.4	(38.8)	$2,571	$105	24.4
Animal Buildings 1&2	741.2	33,550.4	(359.2)	$23,822	$977	24.4
Dormitory	105.1	4,756.2	(50.9)	$3,377	$139	24.4
Laundry/Office	19.9	899.2	(9.6)	$638	$26	24.4
Veterinary Hospital	389.8	17,644.2	(188.9)	$12,528	$514	24.4
Office Annex	319.0	14,438.7	(154.6)	$10,252	$421	24.4
Rhea Facility	22.4	1,014.4	(10.9)	$720	$30	24.4
Vehicle Repair Shop	69.3	3,134.8	(33.6)	$2,226	$91	24.4
Boiler Room/Mason Shop	13.2	597.5	(6.4)	$424	$17	24.4
Carpenter Shop	85.5	3,868.4	(41.4)	$2,747	$113	24.4
Small Animal Facility	1,030.4	46,640.8	(499.4)	$33,116	$1,358	24.4
Green Hill Barn	260.2	11,777.6	(126.1)	$8,362	$343	24.4
Slate Hill Barn	316.0	14,302.2	(153.1)	$10,155	$417	24.4
Rivinus Barn	249.1	11,273.4	(120.7)	$8,004	$328	24.4
Meade Barn	315.4	14,276.9	(152.9)	$10,137	$416	24.4
Waller Barn	309.3	14,009.1	(149.9)	$9,930	$408	24.3
Cons. Res. Center, VA	**5,915.5**	**267,771.0**	**(2,867.1)**	**$190,107**	**$7,799**	**24.4**

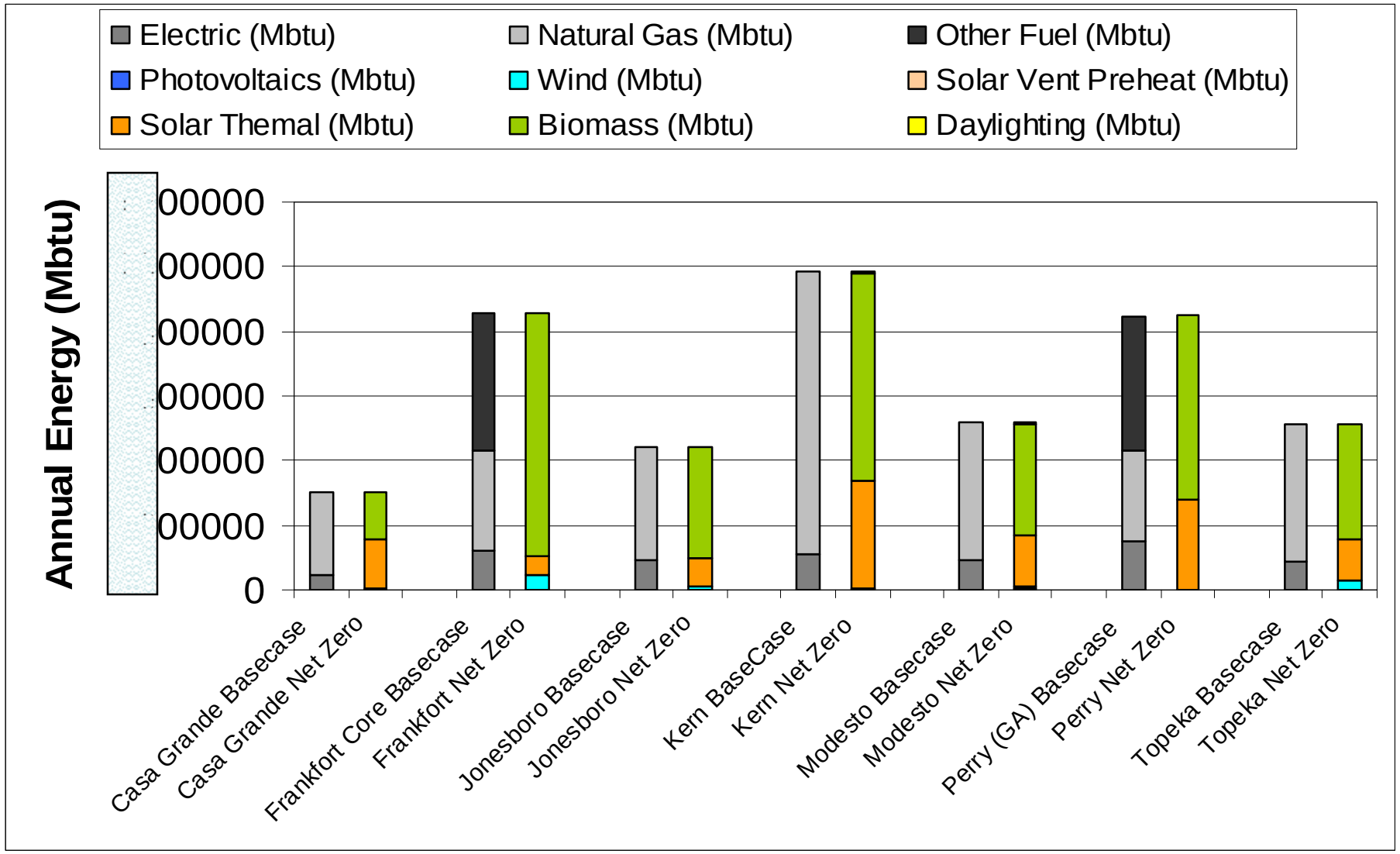
Subsequent Projects

- 7 Frito Lay Plants
- Town of Greensburg, KS
- US Navy San Nicolas Island, CA
- 59 Anheuser Busch facilities

Example: Frito Lay North America Minimum Life Cycle Cost (no constraints)



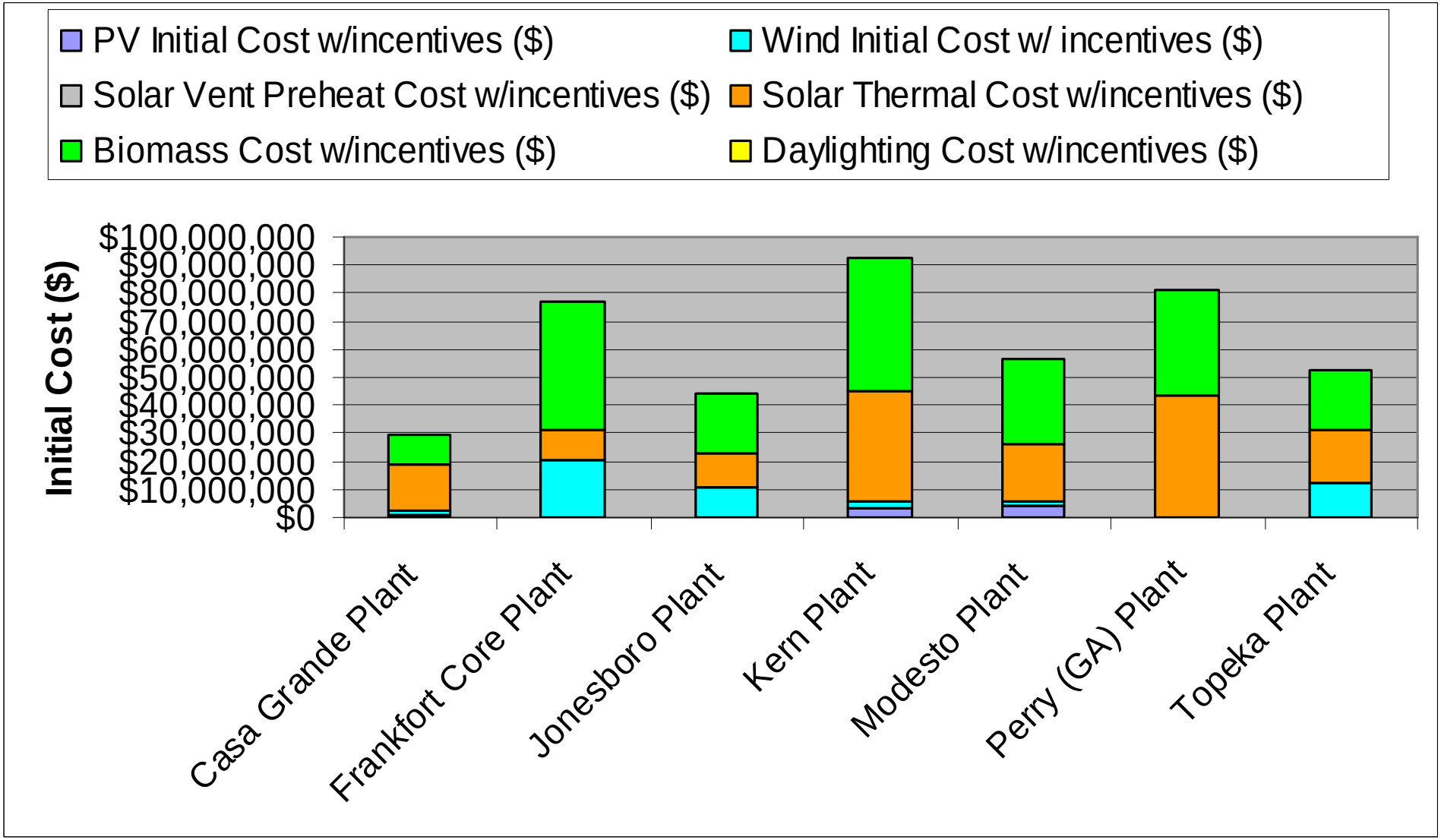
Example: Frito Lay North America
Minimum Life Cycle Cost (Net Zero constraint)



Example: Net Zero Optimization for Seven Manufacturing Plants

	Photovoltaics Size (kW)	Wind Capacity (kW)	Solar Vent Preheat Area (ft2)	Solar Thermal Area (ft2)	Biomass Boiler Size (M Btu/h)	Biomass Cogeneration Size (kW)	Daylighting Office Utility Skylight/Floor Area Ratio	Daylighting Warehouse Skylight/Floor Area Ratio
Casa Grande Plant	200	491	5456	509196	19	1669	2.200%	2.095%
Frankfort Core Plant	0	6187	8953	391989	87	3097	3.850%	1.970%
Jonesboro Plant	0	3107	13098	469621	44	3180	4.896%	3.647%
Kern Plant	1011	1000	10213	1358855	78	4106	3.354%	1.850%
Modesto Plant	1003	998	10327	704140	44	3327	6.105%	3.362%
Perry (GA) Plant	0	0	10322	1529610	74	6020	10.800%	5.200%
Topeka Plant	0	3699	10802	673761	43	2193	3.296%	3.673%

Initial Costs for Each Technology at Each Plant



"All the News That's Fit to Print"

The New York Times

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THURSDAY, NOVEMBER 15, 2007

In Eco-Friendly Factory, Low-Guilt Potato Chips

By ANDREW MARTIN

CASA GRANDE, Ariz. — At Frito-Lay's factory here, more than 500,000 pounds of potatoes arrive every day from New Mexico to be washed, sliced, fried, seasoned and portioned into bags of Lay's and Ruffles chips. The process devours enormous amounts of energy, and creates vast amounts of wastewater, starch and potato peelings.

Now, Frito-Lay is embarking on an ambitious plan to change the way this factory operates, and in the process, create a new type of snack: the environmentally benign chip.

Its goal is to take the Casa Grande plant off the power grid, or nearly so, and run it almost entirely on renewable fuels and recycled water. Net zero, as the concept is called, has the backing of the highest levels of corporate executives at PepsiCo, the parent of Frito-Lay.

There are benefits besides the potential energy savings. Like many other large corporations, PepsiCo is striving to establish its green credentials as consumers become more focused on climate change. There are marketing opportunities, too. The company, for example, intends to advertise that its popular SunChips snacks are made using solar energy.

Frito-Lay's Venture Joins the Rush to Be Green

"We don't know what the complete payoff for net zero is going to be," said Indra K. Nooyi, PepsiCo's chairman and chief executive. "If this works even to 50 or 60 percent of its potential, that is fantastic, and it's so much better than what we already have."

From coast to coast, more companies are thinking about how much fossil fuel they use and ways to conserve energy. Venture capital money is also pouring into fledgling green technology.

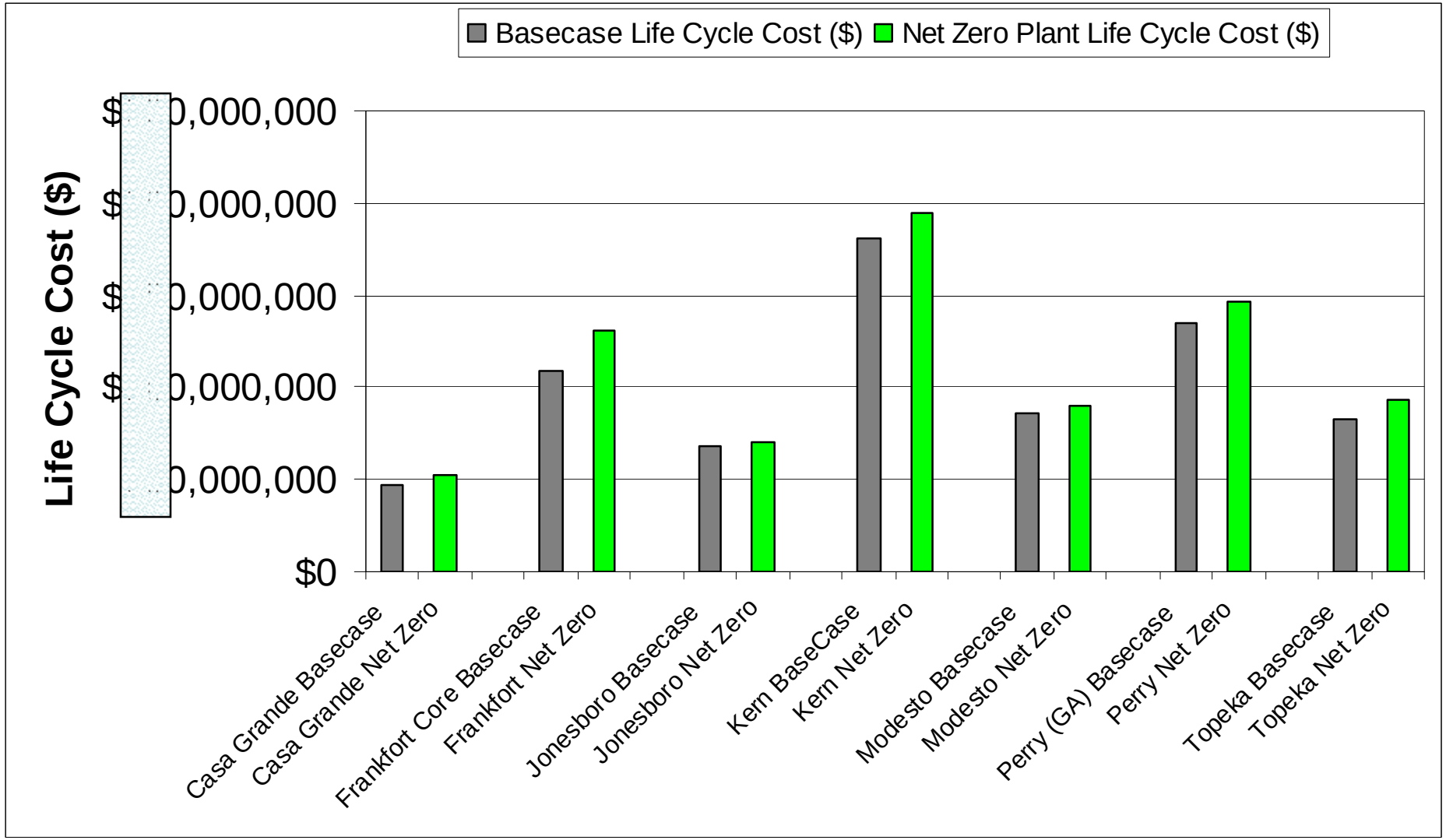
Only a few years ago, Andy Walker, a government engineer, pleaded with companies to tackle the problems but got blank stares. "Now, my phone is ringing off the hook," said Mr. Walker, who works at the National Renewable Energy Laboratory of the Department of Energy in Colorado.

But advocacy groups contend that for all the interest in saving energy, many companies also exaggerate small improvements for marketing purposes.

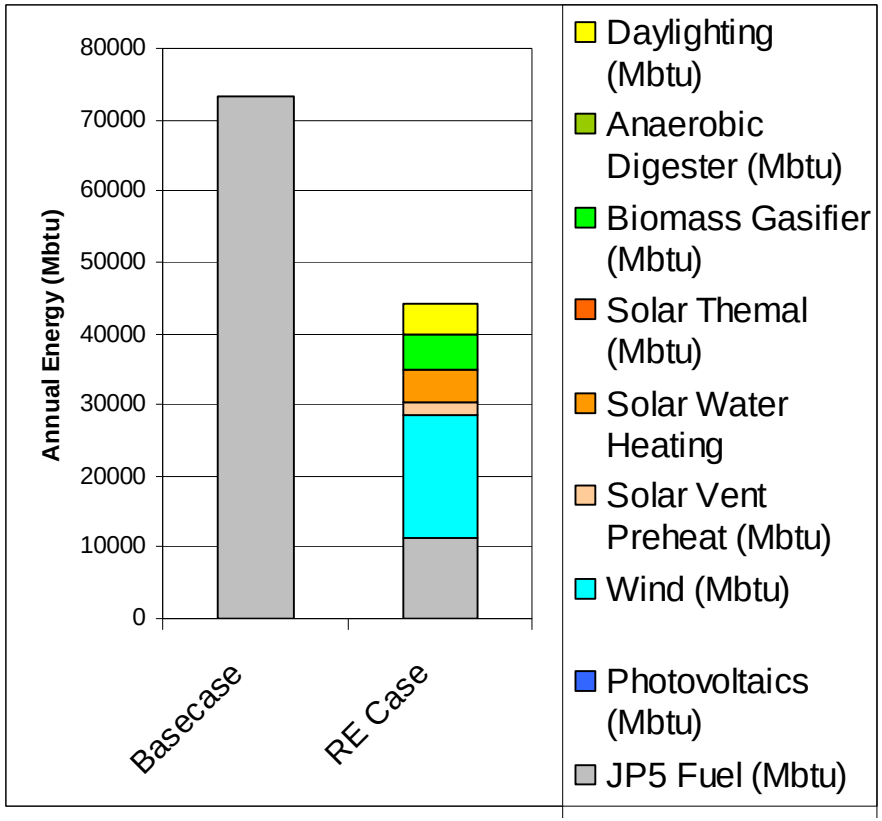
"Now I think there's a transi-

Continued on Page A22

Life Cycle Cost of Each Net Zero Plant versus BaseCase



Example: Minimize Life Cycle Cost
US Navy San Nicolas Island CA



Thank You!