Sustainable Building Study Using Whole-System and Life-Cycle Thinking

2012 REPORT TO THE MID-ATLANTIC, REGION 3 OF THE U.S. GENERAL SERVICES ADMINISTRATION

by

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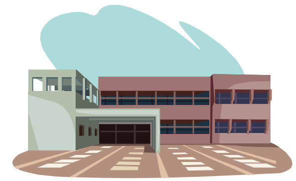
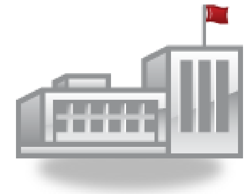
Summary of Approach to Project

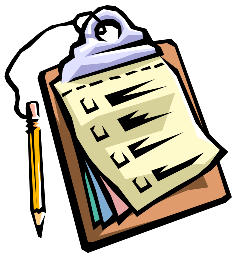
- **Deliverables**

  1) LEED EB O& M and Guiding Principle Analysis
     - Submitted December 28, 2011
     - Establish a baseline for each building's performance, based on existing conditions, with respect to meeting the GSA's Guiding Principles (GP) for Sustainable Existing Buildings.
     - Rate the buildings using the LEED EBOM (version 2009) Checklist and provide a plan to illustrate how the buildings can best achieve LEED EBOM Gold Certification.
  2) Sustainability Audit and LCCA Projects
     - Submitted January 31, 2012
     - Identify projects and practices necessary to satisfy the Guiding Principles and achieve LEED EBOM certification, including costs to implement the recommendations.
  3) Sustainable Building Study Report
     - Submitted March 5, 2012
     - To be discussed today

Project Approach



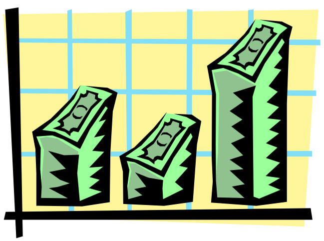




LEED EBOM
Guiding Principles

Projects:
Building Specific and General

SWA/All



LCCA

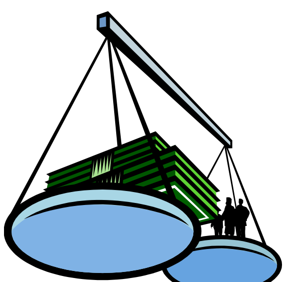
Traditional Life Cycle Cost Analysis
(LCCA)

SWA/RMI

LCA and
External Costs

Life Cycle Assessment
(LCA)

Athena/RMI



Composite
LCCA

Composite Life Cycle Cost Analysis

All

LCA Objectives

1) Benchmark the embodied material and operating energy environmental effects of 3 GSA buildings in Baltimore

- Use readily available LCA tools with the aim to make benchmarking replicable
- Tool and output to provide a basis for assessing potential recommendations going forward

2) Monetize the environmental impact of embodied and operational effects (i.e. determine external cost of pollution)

- Literature review: cast a wide enough net to capture a set of geographically applicable and global effects
- Provide a range of costs that are applicable to other US locales

Externality Costs Defined

Externality Costs

... Those costs borne by society instead of directly by the producer or consumer of the product or service.

These costs take the form of environmental damage or human health effect "cost adders"

Costs not *internalized* in the price of a good or service

Varied methods –

- Cost of control
- Willingness-to-pay
- Estimating damage effects

Considerable controversy and uncertainty is the norm, not the exception ...

Considerable "value judgment" at play

Tendency to put more value on human life than the biosphere that supports human life

Determining externality costs – a stepwise process

1. Consult literature to determine "damages" associated with a sub-set of well study emissions – criteria air pollutants
2. Interpolate other costs of emissions within various LC impact categories using "equivalence" effects
3. Generate a life cycle inventory of emission flows to air, water and land associated with materials and energy life cycles, calculate impact indicators and apply external costs
4. Sum externality costs across the set of LC impact categories to arrive at a total adder cost for material use or energy consumption

Determining externality costs

Conduct literature review

- Reviewed latest research in Europe and N. America
- Much of the external cost literature addresses criteria air pollutants and GHGs from a fuel life cycle perspective

- Two references stood out
  - Muller, Nicholas Z. and Robert Mendelsohn. **"Weighing the Value of a Ton of Pollution."** Regulation. Summer 2010: 20-24.
  - National Research Council of the National Academies**.** **"Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use".** Washington: The National Academies Press, 2009.

Determining externality costs

Muller and Mendelsohn (2010)

- Calculate marginal damage of 6 air pollutants at the US county level

Pollutant	Marginal Damages of Emissions by Spatial Percentile ($/ton)					
	1^{st}	25^{th}	50^{th}	75^{th}	99^{th}	99.9^{th}
Fine Particulate Matter	250	700	1,170	1,970	12,400	41,770
Course Particulate Matter	60	120	170	280	1,960	6,550
Nitrogen Oxides	20	180	250	370	1,100	1,780
Ammonia	100	300	900	2,000	2,062	59,450
Volatile Organic Compounds	40	120	180	280	1,370	4,540
Sulfur Dioxide	220	550	970	1,300	4,130	10,860

1^{st} percentile – small population/rural location, with good air quality

99.9^{th} percentile – large population/urban location, with poor air quality

Baltimore is in the 99^{th} percentile

Determining externality costs

Determined LC impact indicator categories to be supported by the project

- As per available LCA tools & prescribed building sustainability metrics (ISO 21930)
- US EPA TRACI characterization methods provide context

Impact category	Unit equivalence basis (indicator result)	Source of the characterization method	Level of site specificity
Global warming	kg CO_2 - equivalents	TRACI (IPCC,2007)	Global
Acidification	$H^{+\text{ moles}}$ - equivalents	TRACI	Local or regional
Ozone depletion	kg CFC-11- equivalents	TRACI	Global
Eutrophication	kg N water- equivalents	TRACI	Local or regional
Human health: respiratory effects	kg $PM_{2.5}$- equivalents	TRACI	Local or regional
Photochemical smog	kg NO_x- equivalents	TRACI	Local or regional

Determining externality costs

Using Muller and Mendelsohn (2010) price for Ammonia we interpolate the "equivalent cost" (price) of other emissions contributing to the acidification potential impact category measure by spatial percentile

Substance	Emission	Contibution	Normalizing	Marginal Damages of Emissions by Spatial Percentile ($/ton H+moles)					
	Media	EQ Factor	Cost Factor	1^{st}	25^{th}	50^{th}	75^{th}	99^{th}	99.9^{th}
Ammonia	Air	**95.5**	1	**$ 1.05**	**$ 3.14**	**$ 9.42**	**$ 20.94**	**$ 21.59**	**$ 622.51**
Hydrochloric acid	Air	**44.7**	0.4681	$ 0.49	$ 1.47	$ 4.41	$ 9.80	$ 10.11	$ 291.37
Hydrofluoric acid	Air	**81.3**	0.8510	$ 0.89	$ 2.67	$ 8.02	$ 17.82	$ 18.37	$ 529.77
Hydrogen sulfide	Air	**95.5**	0.9999	$ 1.05	$ 3.14	$ 9.42	$ 20.94	$ 21.59	$ 622.48
Nitric acid	Air	**25.9**	0.2713	$ 0.28	$ 0.85	$ 2.56	$ 5.68	$ 5.86	$ 168.86
Nitric oxide	Air	**61.3**	0.6415	$ 0.67	$ 2.02	$ 6.05	$ 13.44	$ 13.85	$ 399.37
Nitrogen dioxide	Air	**40.0**	0.4193	$ 0.44	$ 1.32	$ 3.95	$ 8.78	$ 9.05	$ 261.03
Nitrogen oxides	Air	**40.0**	0.4193	$ 0.44	$ 1.32	$ 3.95	$ 8.78	$ 9.05	$ 261.03
Phosphoric acid	Air	**49.8**	0.5213	$ 0.55	$ 1.64	$ 4.91	$ 10.92	$ 11.25	$ 324.49
Sulfur dioxide	Air	**50.8**	0.5319	$ 0.56	$ 1.67	$ 5.01	$ 11.14	$ 11.48	$ 331.11
Sulfur oxides	Air	**50.8**	0.5319	$ 0.56	$ 1.67	$ 5.01	$ 11.14	$ 11.48	$ 331.11
Sulfur trioxide	Air	**40.6**	0.4255	$ 0.45	$ 1.34	$ 4.01	$ 8.91	$ 9.19	$ 264.89
Sulfuric acid	Air	**33.0**	0.3457	$ 0.36	$ 1.09	$ 3.26	$ 7.24	$ 7.46	$ 215.22

Determining externality costs

Muller and Mendelsohn (2010) externality costs work for other regional effect measures on a spatial percentile basis

NRC (2009) report used to establish low, mid and high values for global climate change effects – marginal costs ranged by two order of magnitude –

- Low - \$1/ton CO_2 equivalent
- Mid - \$30/ton CO_2 equivalent
- High - \$100/ton CO_2 equivalent

Relied on Maryland Genuine Progress Indicator for cost of Ozone Depletion Potential - \$5,500/ton

Externality costs by impact indicator category

$/ton – **Bold** values applied to Baltimore

Impact Category	Low	Mid	High			
GWP	1	**30**	100			
ODP		**5,500**				
	1st	25th	50th	75th	99th	99.9th
AP	1	3	9	21	**22**	593
EP	6	52	73	107	**319**	516
SP	32	95	142	221	**1,080**	3,580
REP	250	700	1170	1970	**12,400**	41,770

Externality Cost of Electricity Use in Baltimore

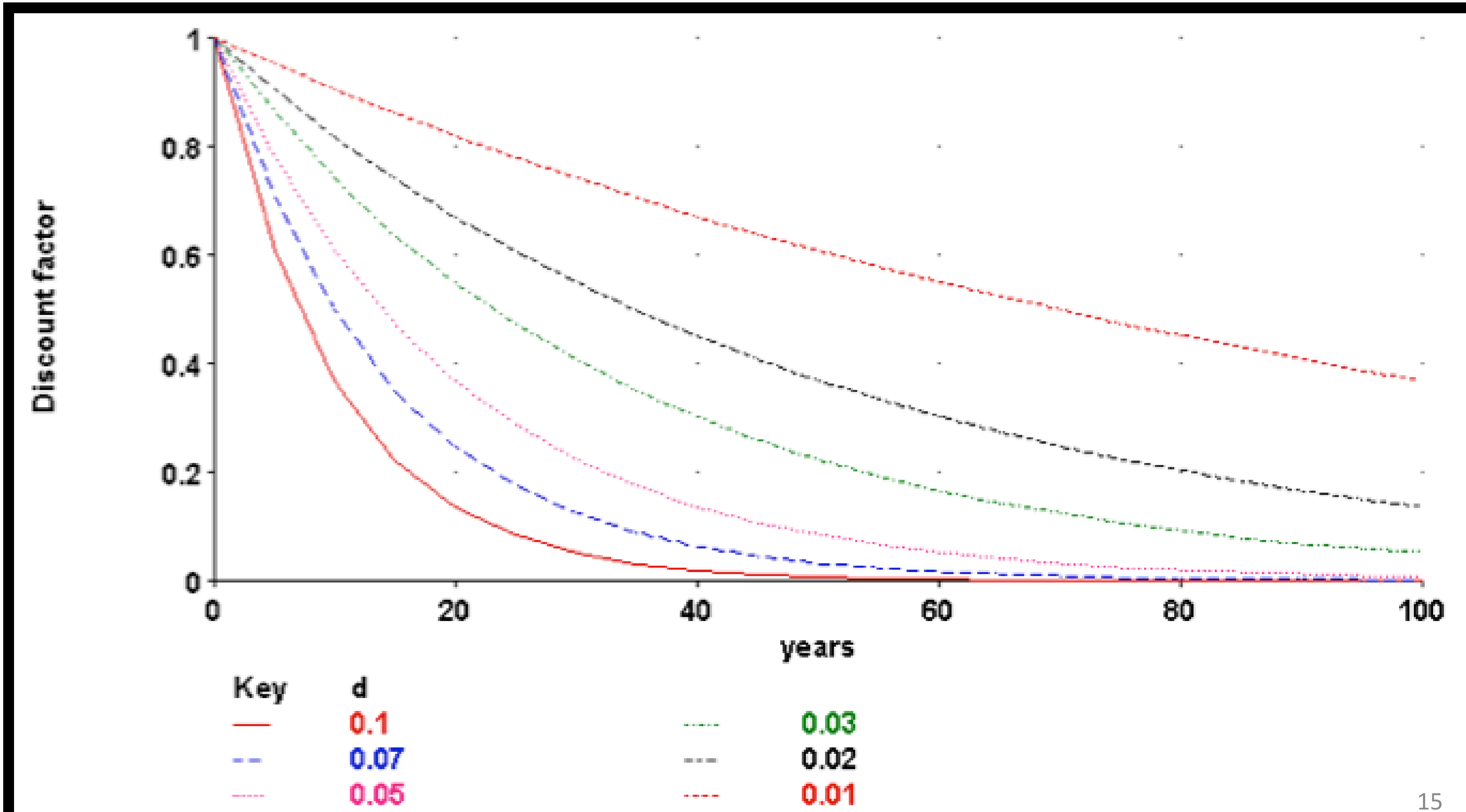
Impact Category	Environmental Impact of 100 kWh of electricity	Mid or 99th percentile External cost $/kg	External cost $/100 kWh	External cost $/kWh
Global Warming Potential (kg CO2 eq)	6.37E+01	$0.03	$1.91	$0.02
Acidification Potential (moles of H+ eq)	2.30E+01	$0.02	$0.49	$0.00
HH Respiratory Effects Potential (kg PM2.5 eq)	1.29E-01	$12.40	$1.60	$0.02
Eutrophication Potential (kg N eq)	5.65E-04	$0.32	$0.00	$0.00
Ozone Depletion Potential (kg CFC-11 eq)	1.69E-11	$55.00	$0.00	$0.00
Smog Potential (kg NOx eq)	1.05E-02	$1.08	$0.01	$0.00
		Total	**$4.02**	**$0.04**

Externality Costs of Various Fuels

Fuel Type	External Cost
1000 kWh of electricity (Maryland)	$39.83
1000 kWh of electricity (US average)	$30.96
1 short ton of steam (Veolia, Baltimore)*	$10.04
1 short ton of steam (100% N. Gas)	$11.36
1000 ton.hrs chilled water (Veolia, Baltimore)	$48.11
1000 ton.hrs chilled water (US Average)	$47.53
1000 L (264 US gall.) of Fuel Oil	$97.70
*Baltimore Veolia Steam: 60% municipal solid waste, 40% natural gas	

Discounting Externality Costs in LCCA

Environmental impacts can have a cumulative long term effect – spanning generations. Discounting at rates of more than 3% leads to nearly zero $ impact at year 100, which allows present consumption at the expense of future generations



Objective #2 - Whole Building Benchmarking

Benchmark the life cycle embodied material and operating energy environmental effects of 3 GSA buildings in Baltimore

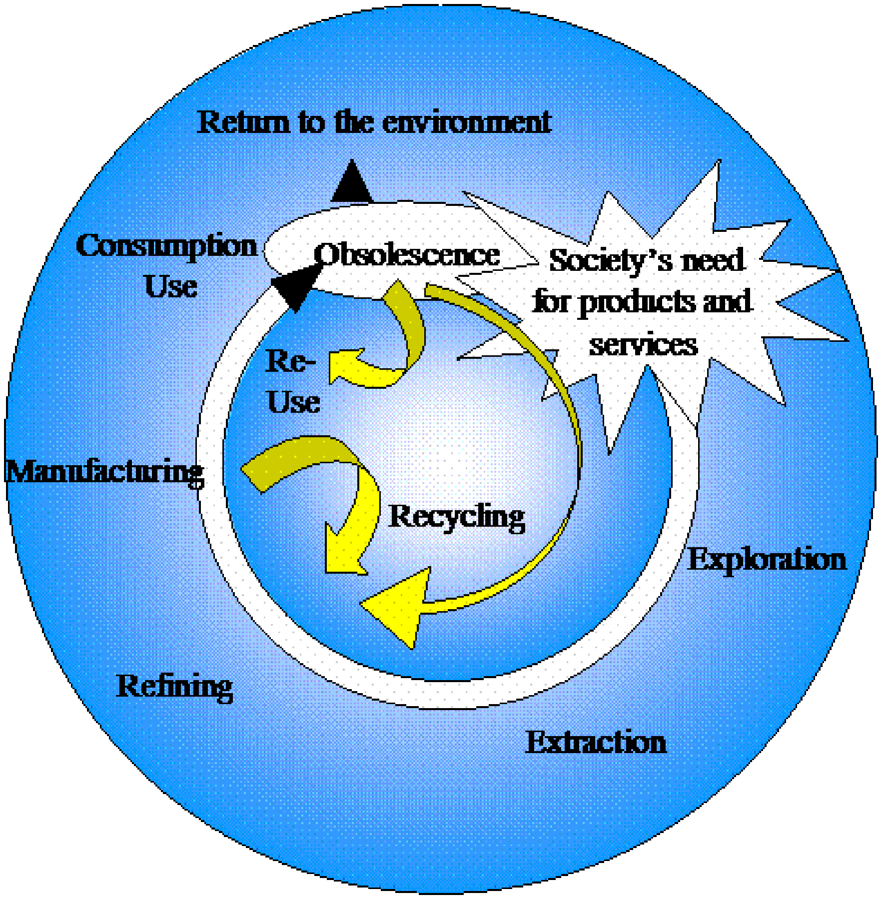
- Use readily available LCA tools with the aim to make benchmarking replicable
- Buildings are of various vintages, but modeled as built today
- Tool and output provide a basis for assessing potential recommendations going forward

LCA Defined

Life Cycle Assessment

... tracks the physical environmental flows from and to the environment and the potential environmental impacts throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment and final disposal.

[ISO 14040:2006]



LCA Example – Electricity from coal combustion

Prior to end use, resources are used and emissions created to produce and deliver energy

Site energy use estimates just one part of the story

Source energy & pre-combustion effects

Whole Building Benchmarking

LCA Tools:

- **Athena Impact Estimator for Buildings software**
  - Whole building LCA focus (structure and envelope)
  - Capable of including operating energy effects
- **NIST's BEES software**
  - Interior product fit-out focus (finished surfaces)
  - LCCA component too

LCA Tools

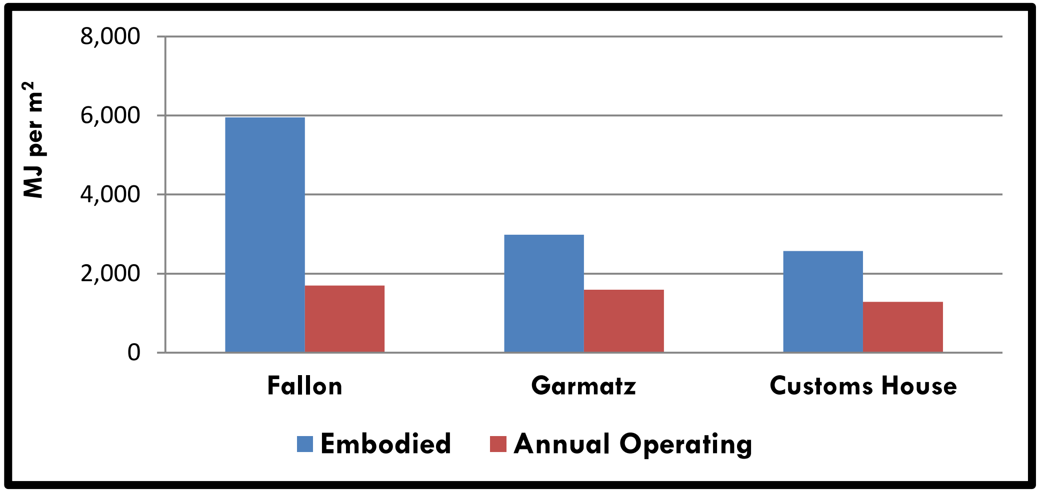
- Both the IE and BEES are concept or schematic design tools.
  - Project called for forensic analysis of existing buildings using provided drawings
- Both tools support US EPA (TRACI)* impact categories

Global Warming	Fossil Fuel Consumption
Acidification	Smog Formation
Eutrophication	Respiratory effects
Ozone depletion	

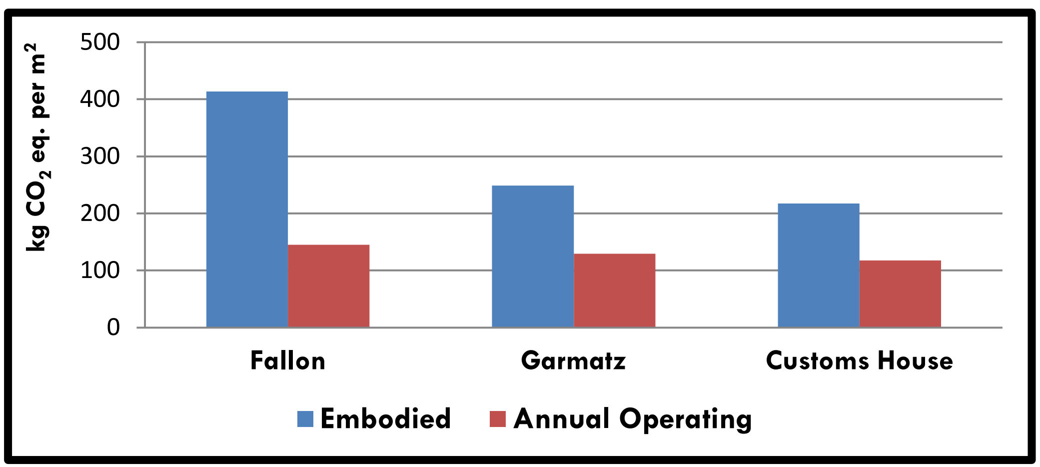
*Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI)

LCA Benchmark Results (per m^{2})

Embodied and Annual Operating Fossil Fuel Consumption



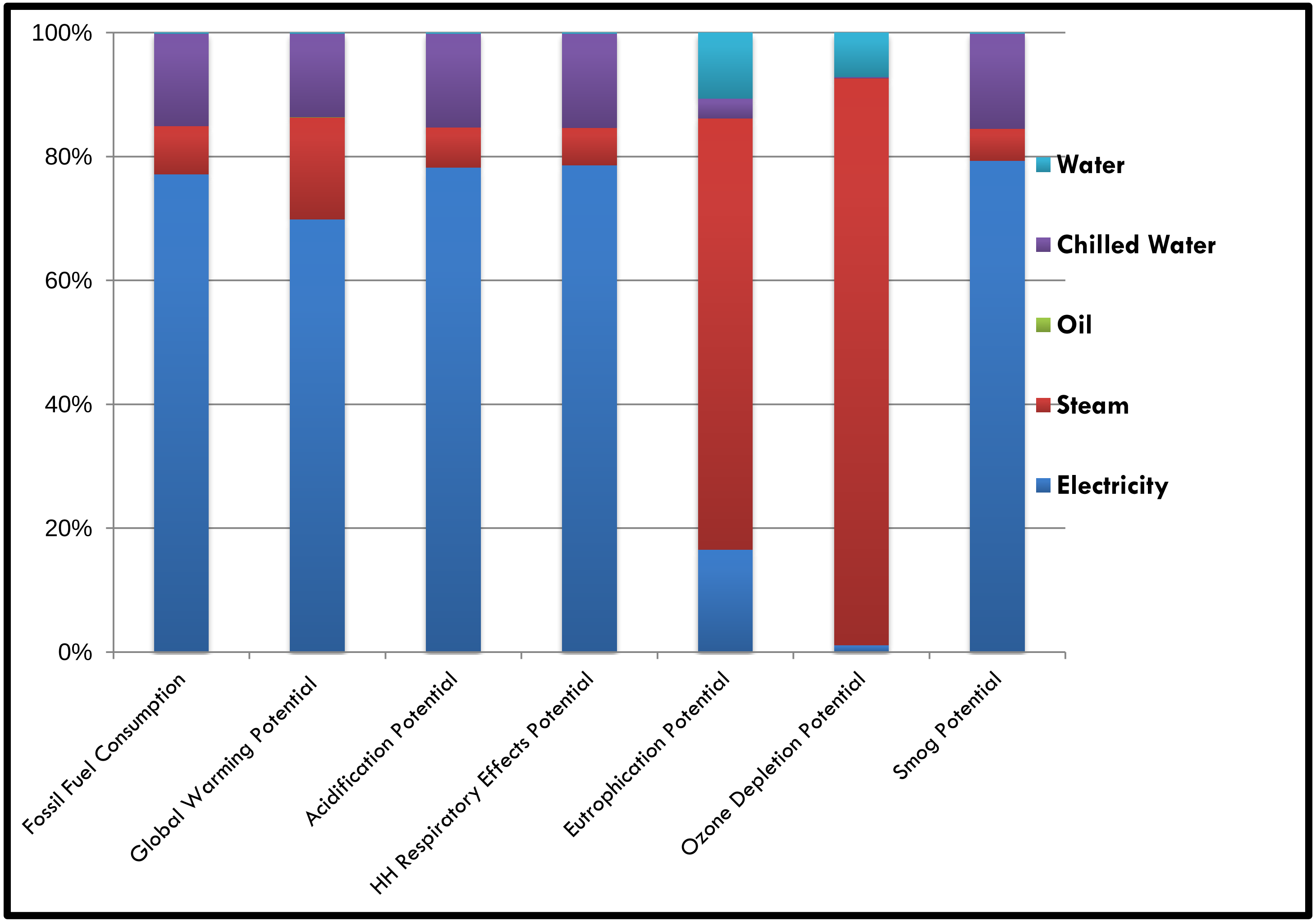
Embodied and Annual Operating Global Warming Potential



- All 3 buildings dominated by operating energy effects
- Equivalent to 2 to 5 years of embodied effects
- Typically operating energy accounts for 80% of the total GWP over 75-yr building life
- For Garmatz and Customs House, operating energy GWP value is closer to 95%

Closer Look at Operating Energy Impact

Garmatz Annual Operating Energy - % Contribution by Fuel Type



LCA of Sustainability Measures

Measures and Tools

- 24 improvement measures assessed from a life cycle perspective (physical environmental flows + externality effects)
  - 10 general measures – LEED/GSA Sustainable Guidelines oriented, modeled using an average US perspective
  - 14 were Baltimore building specific, modeled specific to the building's location and unique source energy
- Some measures had both an embodied and operating energy component (PV), others were only operating energy oriented (reduce plug loads) and others were more operational (cleaning products)

LCA of Sustainability Measures

Measures and Tools ....continued

- Tools used to estimate physical environmental flows:
  - Impact Estimator for Buildings (embodied and operational)
  - BEES - Building for Environmental and Economic Sustainability
  - EPA WaRM Model – solid waste management
  - EPA "Climate Leaders Simplified GHG Emissions Calculator"
  - SimaPro – LCA modeling tool with background databases
- With the environmental flows per impact category determined for each recommendation, it was a matter of applying the externality costs per category indicator

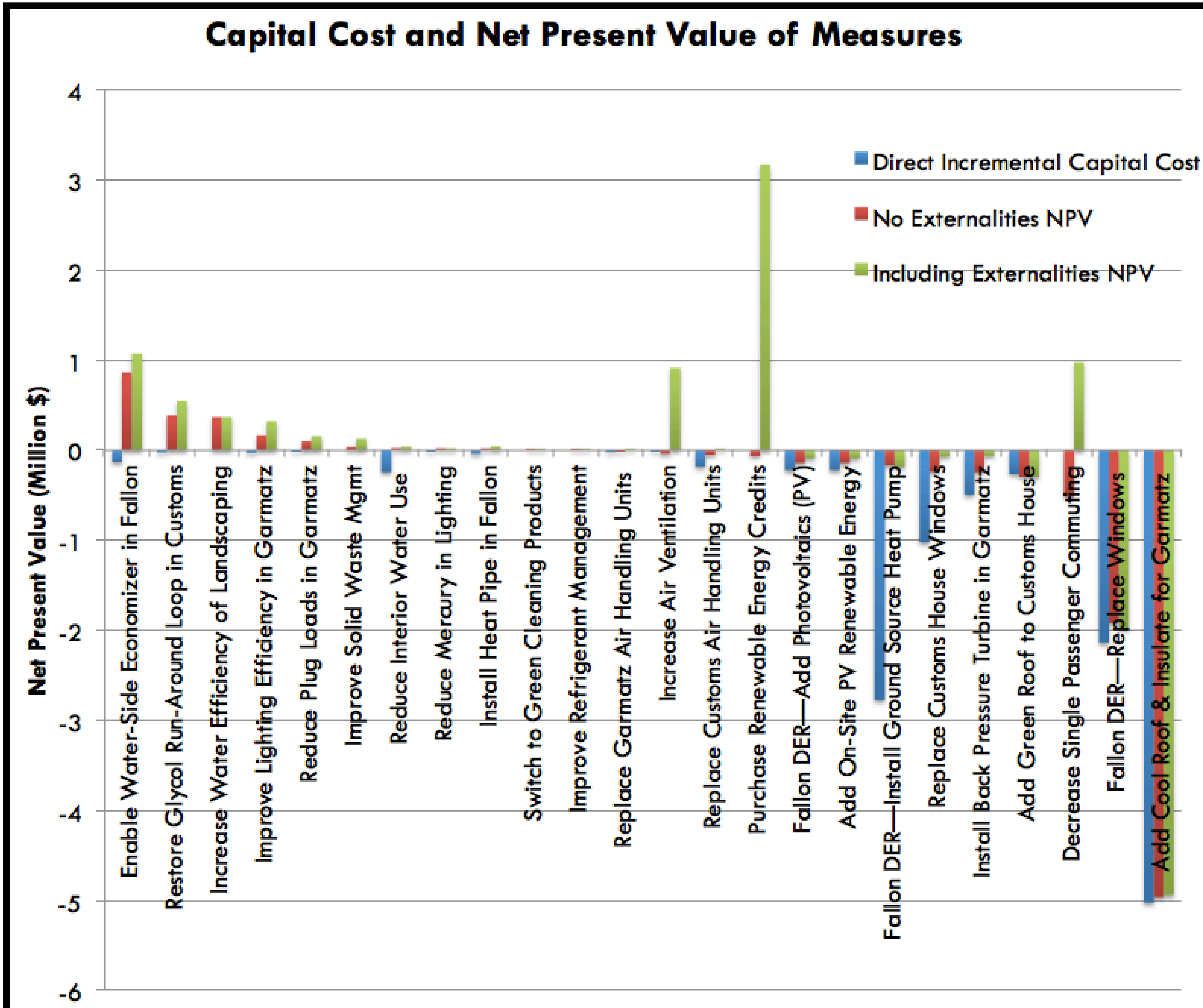
Sustainable Measures Results

	Measure	Change in 20-yr. GWP (m. tons CO2e)	Total 20-yr. External cost ($)
	General Recommendations		
1	Improve Solid Waste Mgmt	(3,429)	$(100,000)
2	Increase Air Ventilation	215	$14,000
3	Improve Refrigerant Management	(9)	$(600)
4	Switch to Green Cleaning Products	(1.5)	$(70)
5	Decrease Single Passenger Commuting	(3,749)	$(110,000)
6	Increase Water Efficiency of Landscaping	(0.5)	$(35)
7	Reduce Interior Water Use	(353)	$(22,000)
8	Reduce Mercury in Lighting	n/a	(3)
9	Purchase Renewable Energy Certificates	(59,000)	$(3,700,000)
10	Install On-site PV Renewable Energy	(888)	$(60,000)

Sustainable Measures Results

	Measure	Change in 20-yr. GWP	Total 20-yr. External cost
		(m. tons CO2e)	($)
	Garmatz Courthouse Specific		
11	Install Back Pressure Turbine	(3,118)	$(210,000)
12	Replace Air Handling Units	(1,166)	$(80,000)
13	Add Cool Roof & Insulation	604	$(27,000)
14	Reduce Plug Loads	(1,100)	$(69,000)
15	Improve Lighting Efficiency	(3,020)	$(190,000)
	Total Garmatz Building	**(7,800)**	**$(570,000)**

Results of LCCA and LCCA with Externality Calculations



Results of LCCA and LCCA with Externality Calculations

#	Measure	Direct Cost NPV	Composite NPV	Building
1.	Solid Waste Management	$36,810	$126,435	General
2.	**Indoor Air Quality**	**($40,043)**	**$913,590**	**General**
3.	Refrigerant Management	$74	$596	General
4.	Green Cleaning	$1,438	$1,498	General
5.	**Transportation**	**($516,995)**	**$976,865**	**General**
6.	Landscaping	$368,339	$368,369	General
7.	Indoor Water Use	$23,446	$41,153	Garmatz
8.	Mercury in Lighting	$20,792	$20,797	General
9.	**Off-Site Renewable Energy**	**($64,090)**	**$3,175,016**	**Garmatz**
10.	On-Site Renewable Energy	($139,199)	($88,752)	Fallon
11.	Co-Generate Electricity	($243,578)	($61,552)	Garmatz
12.	**Air Handling Unit Replacement**	**($50,882)**	**$17,354**	**Fallon**
13.	Cool Roof	($4,962,505)	($4,939,227)	Garmatz
14.	Reduce Plug Loads	$97,478	$157,410	Garamtz
15.	Lighting Retrofits	$166,627	$320,128	Garmatz
16.	**Air Handling Unit Replacement**	**($2,482)**	**$12,747**	**Custom House**
17.	Green Roof	($295,405)	($297,122)	Custom House
18.	Replace Windows	($236,959)	($68,282)	Custom House
19.	Install Heat Pipe	$19,639	$43,536	Custom House
20.	Repair Glycol Run-Around Loop	$388,589	$545,060	Fallon
21.	Enable Water-Side Economizer	$862,021	$1,072,337	Fallon
22.	Deep Energy Retrofit—Add PV	($139,199)	($88,752)	Fallon
23.	Deep Energy Retrofit—Replace Windows	($1,922,150)	($1,986,152)	Fallon
24.	Deep Energy Retrofit—GSHP	$40	($3,913,027)	Fallon

Breakdown of the Measures

11 Measures with Positive NPVs – both Direct and External
7 Measures with Negative NPVs – both Direct and External
1 Measure with Positive Direct NPV but Negative NPV after External Costs (GSHP)
5 Measures with Positive NPVs only after External Costs are applied

Measure Breakdown:

- 7 General Measures
- 6 Garmatz Measures
- 7 Fallon Measures (3 Deep Energy)
- 4 Custom House Measures

Highest Composite NPV = RECs
Lowest Composite NPV = Cool Roofs (or GSHP, depending on savings)

LEED EBOM and Guiding Principles

LEED EBOM Category	GP	Credit(s)	Details
Sustainable Sites		SSc4	Transportation (Measure 5)
		SSc7.2	Cool Roof (M 13), Green Roof (M 17)
Water Efficiency	x	WEc3	Landscaping (Measure 6)
	x	WEc2	Indoor Water Use (Measure 7)
Energy & Atmosphere	x	EAc5	Refrigerant Management (Measure 3)
		EAc4	Off-Site Renewable Energy (Measure 9)
	x	EAc4	On-Site Renewable Energy (Measure 10)
	x	EAp2/c1	Energy Efficiency (M11, 12, 14-16, 18-24)
Materials & Resources	x	MRc7	Solid Waste (Measure 1)
		MRc4	Mercury in Lighting (Measure 8)
Indoor Environmental Quality	x	IEQc1.3/4	Increased Airflow/Filters (Measure 2)
	x	IEQc3.3	Green Cleaning (Measure 4)

Measure LEED Summary: SS = 3, WE = 2, EA = 15, MR = 2, IEQ = 2

Findings

- 3 Measures are Direct Costs to GSA that have significant Positive NPVs with Externalities
  - Indoor Air Quality
  - Transportation
  - Renewable Energy Credits
- 3 Measures with Negligible LCA Impact
  - Green Cleaning ($1,438 Direct NPV, $60 positive External Cost)
  - Mercury ($20,792 Direct NPV, $5 positive External Cost)
  - Refrigerant Management ($74 Direct NPV, $522 External Cost)
- 8 Measures had Direct Cost Positive NPVs
  - Recycling
  - Landscaping
  - Indoor Water Use
  - Energy: Plug Loads, Lighting, Heat Pipe, Glycol Run-Around, Water-Side Econ

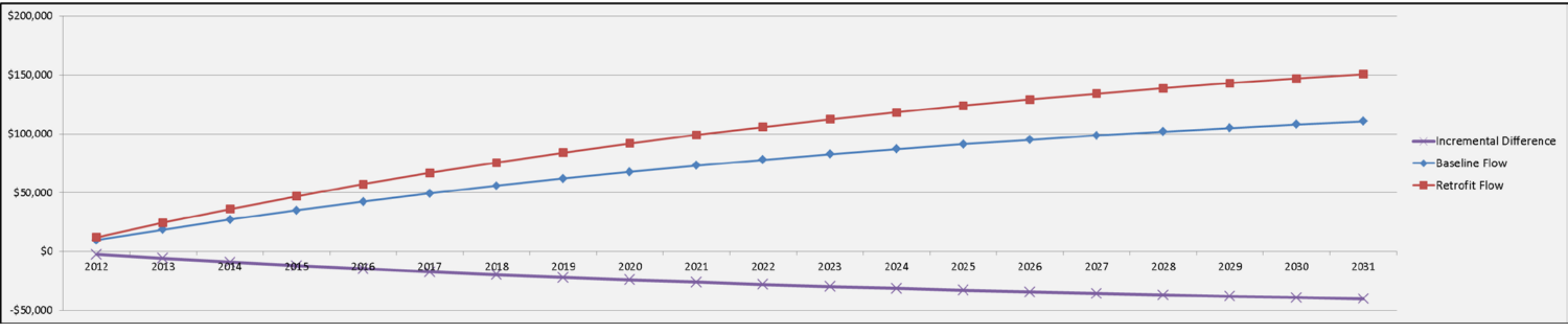
- 60% of Measures focus on Energy

- External Costs for Energy-Related Measures increase positive NPVs by factor of 1.25 – 2.2

Findings

- 8 Big Ticket Measures had Negative NPVs even with External Costs
  - PV
  - Co-Generation
  - Cool Roof
  - Green Roof
  - Replace Windows at Custom House
  - (3) Deep Energy Retrofit Measures
- 5 Measures had Negative Direct Cost NPVs and shifted to Positive with External Costs
  - Indoor Air Quality
  - Transportation
  - RECs
  - AHU Replacement – Garmatz
  - AHU Replacement – Custom House
- Of these 5, all had significant External Cost Impacts

Measure 2: Indoor Air Quality - General



External Costs:

Energy = $\$0.02/ft^2$

Productivity = $(1.52/ft^2)$

Area = 36,453 ft^2

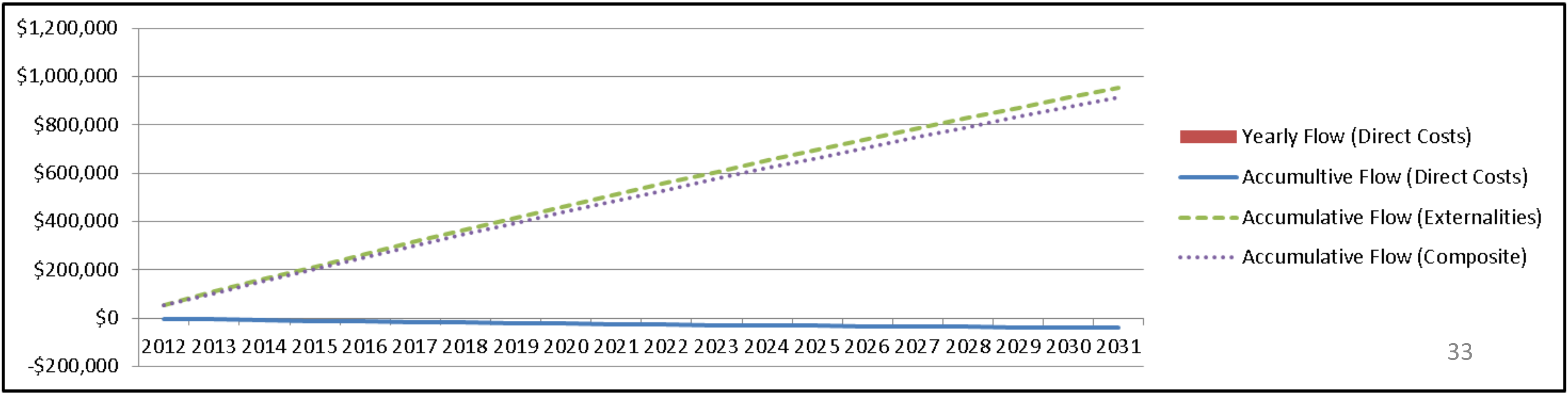
IAQ			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$90,460	
		Capital Costs	$0	
		O&M Costs	$20,216	
		Total	$110,675	$32,191
	20 Year Retrofit Costs	Energy Costs	$120,755	
		Capital Costs	$1,609	
		O&M Costs	$28,355	
		Total	$150,719	($921,442)
	Net Present Value (NPV)		**($40,043)**	**$953,633**
	Composite NPV		**$913,590**	

Annual Incremental Costs:

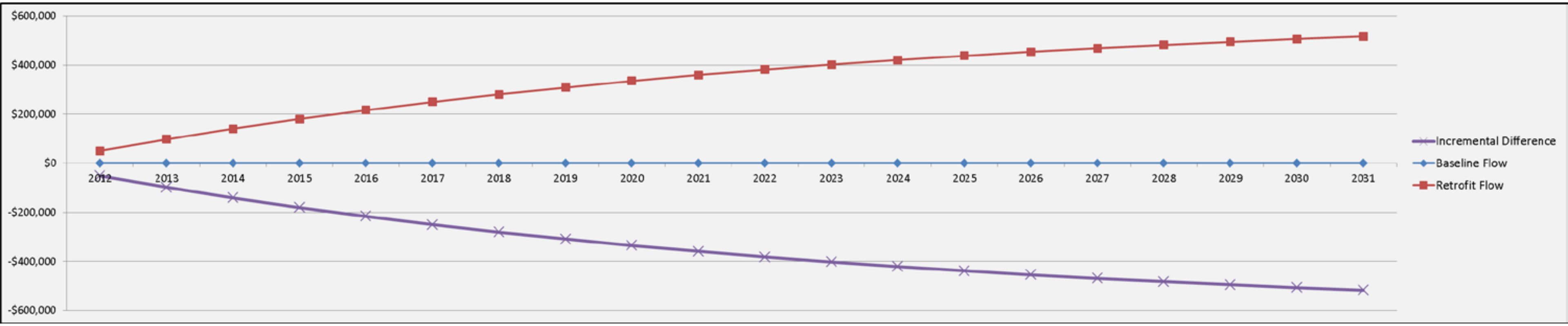
Direct Cost = $798

External Cost = ($51,030)

Net Cost = ($50,232)



Measure 5: Transportation - General (1 of 2)



Baseline assumes GSA pays nothing for Commuting (Employee Cost)
Proposed assumes GSA pays full price of Train Fare for 66 Commuters

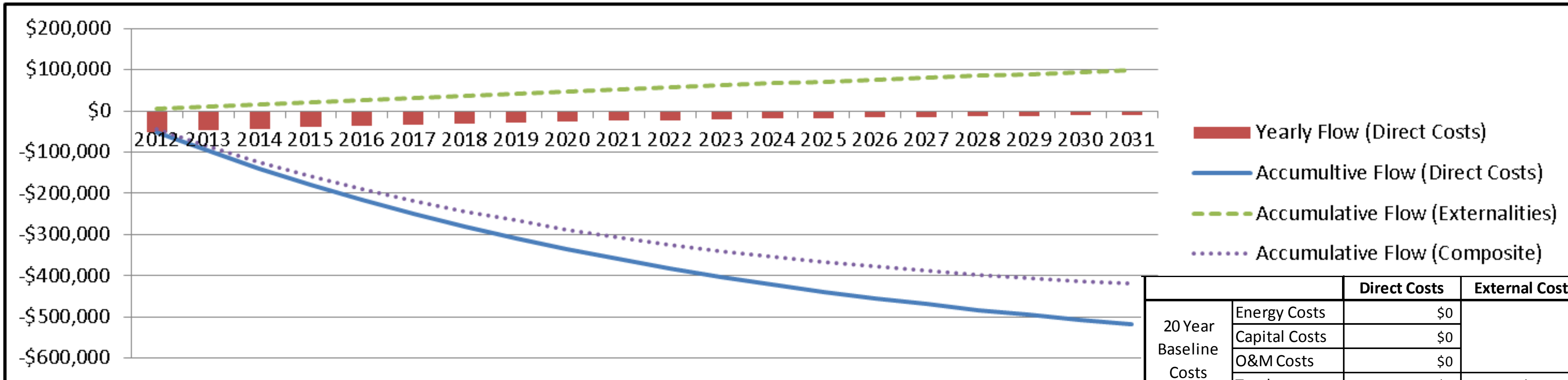
Proposed Modeled with 2 Scenarios:

1. No cost for Building Occupant Gasoline Cost included
2. Cost for Building Occupant Gasoline Cost shown as External Cost

GWP of the reduced single passenger cars included in both Proposed Scenarios

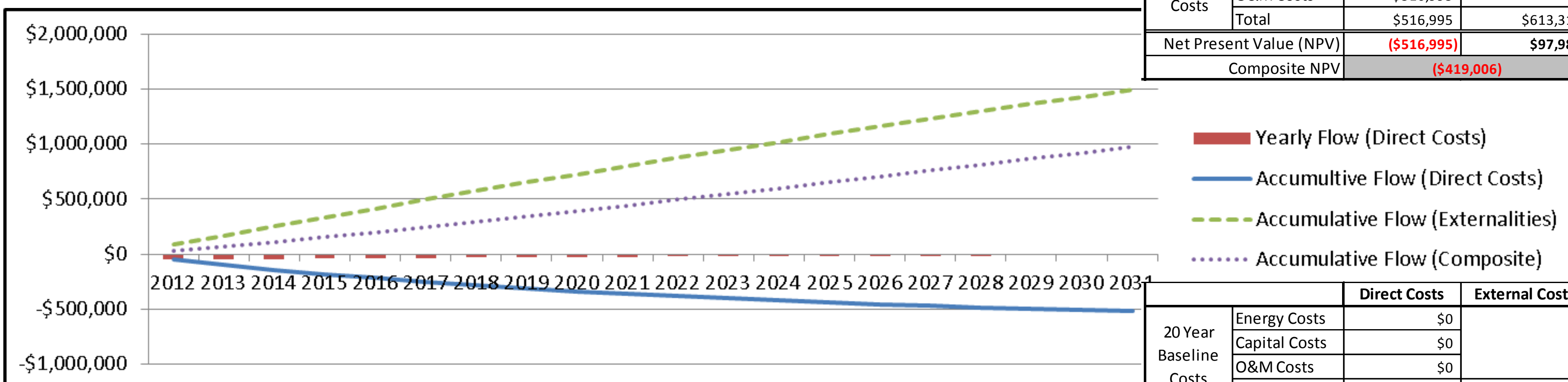
Measure 5: Transportation - General (2 of 2)

Scenario 1: Gasoline Costs Excluded



		Direct Costs	External Costs
20 Year Baseline Costs	Energy Costs	$0	
	Capital Costs	$0	
	O&M Costs	$0	
	Total	$0	$711,299
20 Year Retrofit Costs	Energy Costs	$0	
	Capital Costs	$0	
	O&M Costs	$516,995	
	Total	$516,995	$613,310
Net Present Value (NPV)		**($516,995)**	**$97,989**
Composite NPV		**($419,006)**	

Scenario 2: Gasoline Costs Included



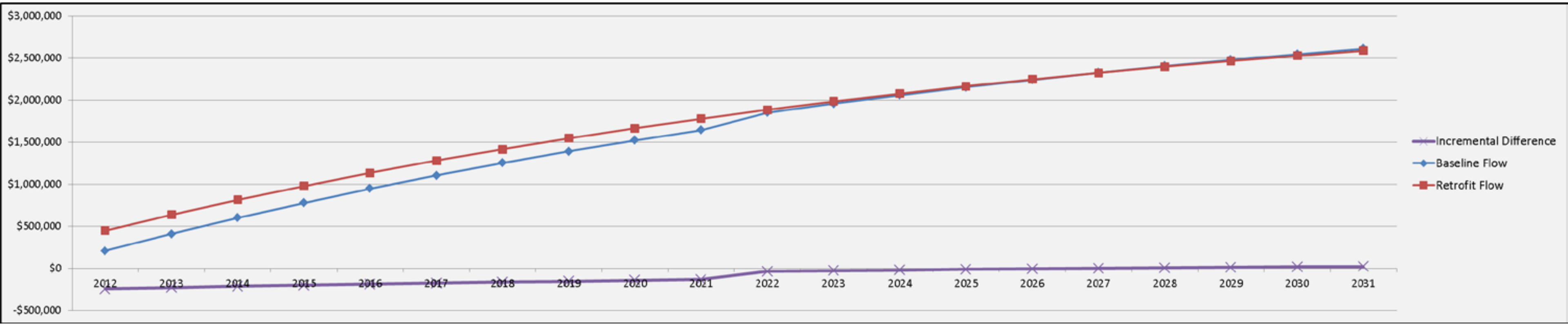
		Direct Costs	External Costs
20 Year Baseline Costs	Energy Costs	$0	
	Capital Costs	$0	
	O&M Costs	$0	
	Total	$0	$2,107,170
20 Year Retrofit Costs	Energy Costs	$0	
	Capital Costs	$0	
	O&M Costs	$516,995	
	Total	$516,995	$613,310
Net Present Value (NPV)		**($516,995)**	**$1,493,860**
Composite NPV		**$976,865**	

Baseline External Costs:

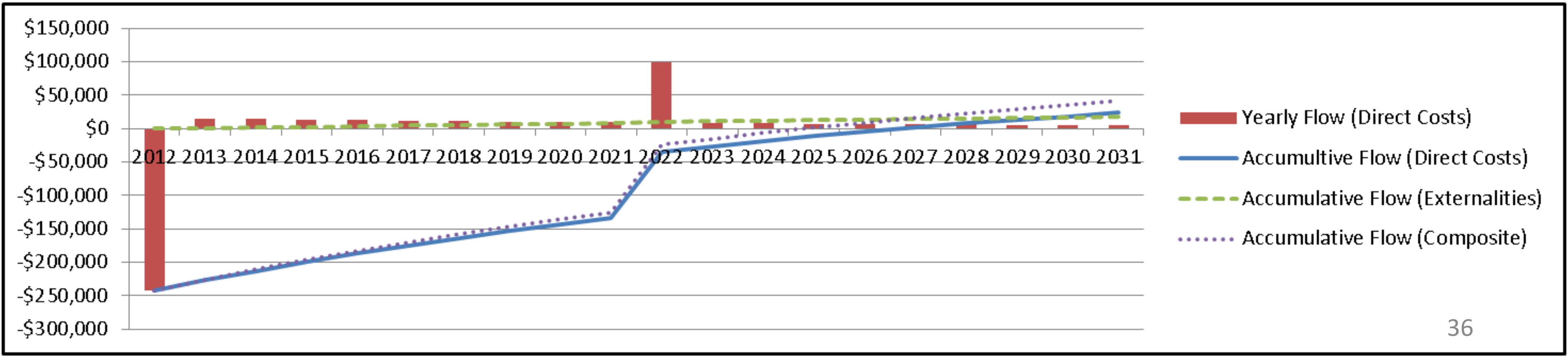
Scenario 1 = $ 40,812

Scenario 2 = $120,920 (includes $80,102 for gasoline)

Measure 7: Indoor Water Use - Garmatz



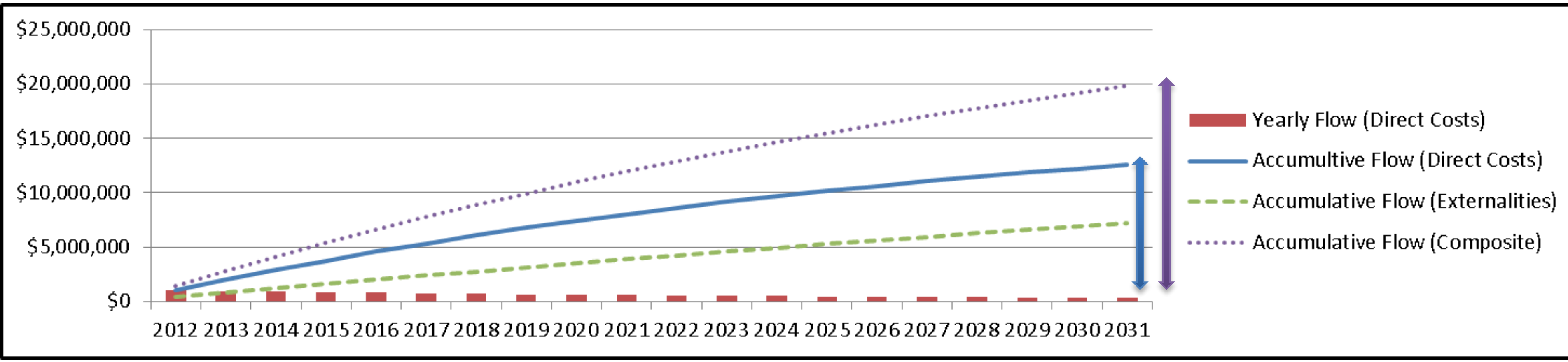
Interior Water Use Reductions			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$2,438,223	
		Capital Costs	$90,668	
		O&M Costs	$84,031	
		Total	$2,612,922	$823,386
	20 Year Retrofit Costs	Energy Costs	$2,256,432	
		Capital Costs	$242,073	
		O&M Costs	$90,971	
		Total	$2,589,476	$805,680
	Net Present Value (NPV)		**$23,446**	**$17,707**
	Composite NPV		**$41,153**	



GSA is not just talking about net zero energy…

The present value of presumed energy savings equals the capital available to spend and still reach a neutral NPV

Fallon Federal Building's "Deep Savings Budget"



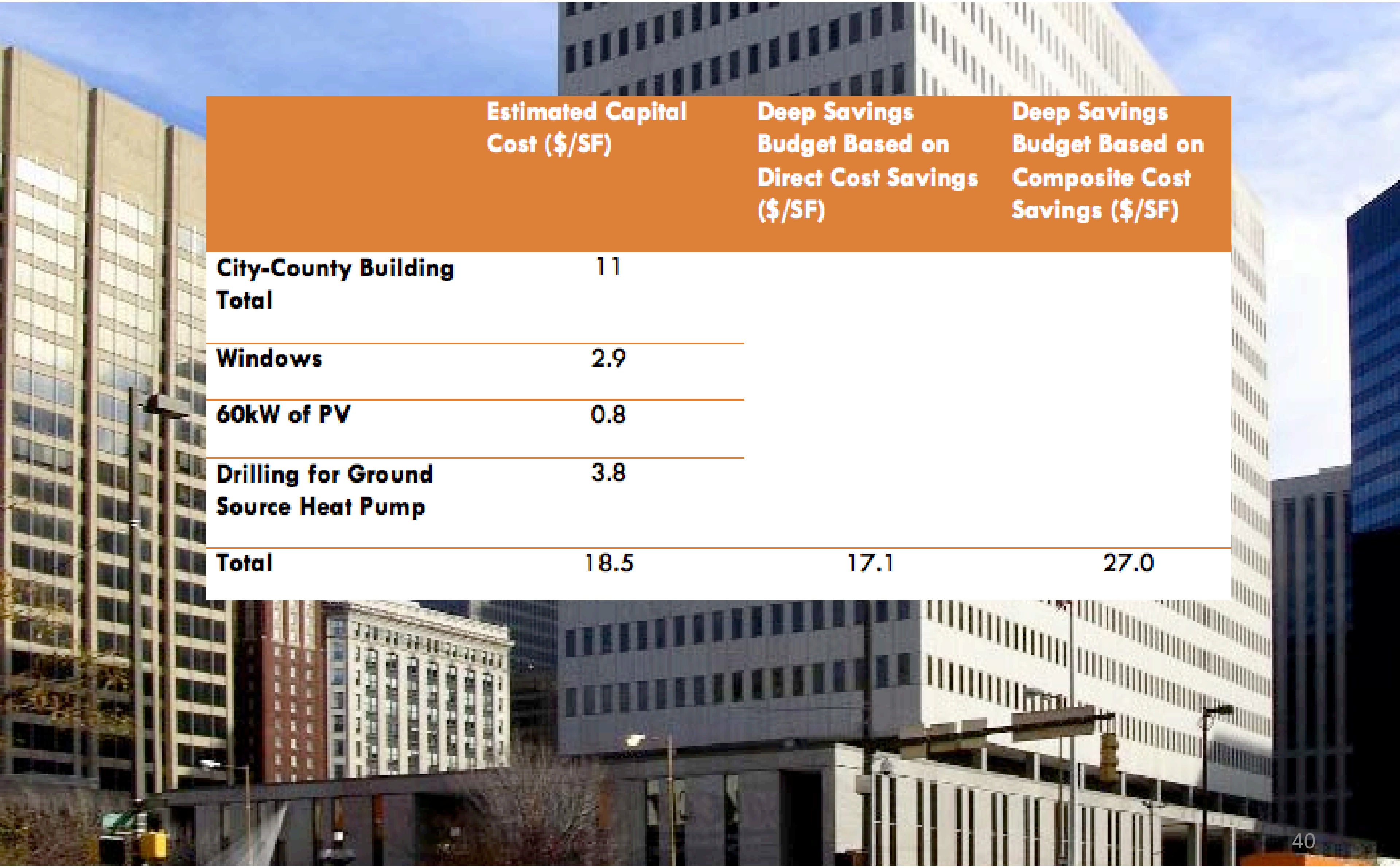
	MMBtu	*MMBtu*	*USD*	*% decrease*	*Target*	*MMBtu*	*USD*	*USD*	*USD*	*USD*	*USD*	*USD*
FACILITY	TOTAL SITE ENERGY USE	TOTAL SOURCE ENERGY USE	TOTAL COST	TARGET ENERGY GOAL	PORTFOLIO MANAGER SCORE	TARGET SITE ENERGY USE	TARGET ENERGY COST	ANNUAL DIRECT COST SAVINGS	ANNUAL EXTERNAL COST SAVINGS	NPV OF DIRECT COST SAVINGS*	NPV OF EXTERNAL COST SAVINGS*	**COMPOSITE NPV OF COST SAVINGS***
Office Building	78,733.74	148,803.10	$2,056,967	50%	98	39366.871	$1,028,484	$1,028,484	$415,665	$12,567,038	$ 7,243,448	$19,810,486

Conducted a pre-feasibility, order-of-magnitude estimate of capital cost required to achieve such deep savings

Indianapolis City-County Building (1962)
731,000 SF high rise
ENERGY STAR rating 50 –> 95
Cost: $11/SF

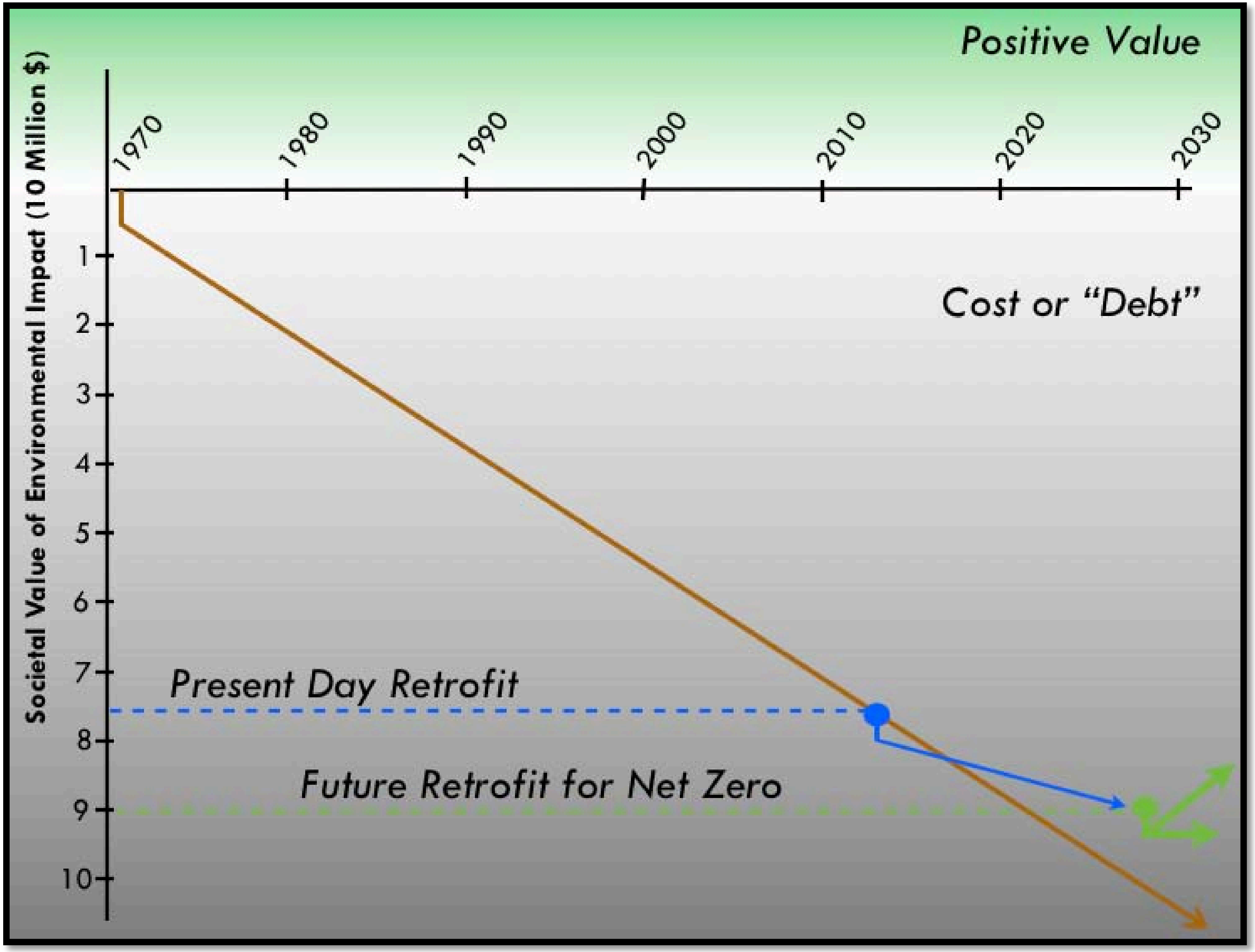
Fallon Federal Building (1973)
735,000 SF high rise
ENERGY STAR rating 67 –> 98(?)
Cost: $11+(?)/SF

The Fallon Building could achieve 50% energy savings within a Deep Savings Budget based on composite cost



	Estimated Capital Cost ($/SF)	Deep Savings Budget Based on Direct Cost Savings ($/SF)	Deep Savings Budget Based on Composite Cost Savings ($/SF)
City-County Building Total	11		
Windows	2.9		
60kW of PV	0.8		
Drilling for Ground Source Heat Pump	3.8		
Total	18.5	17.1	27.0

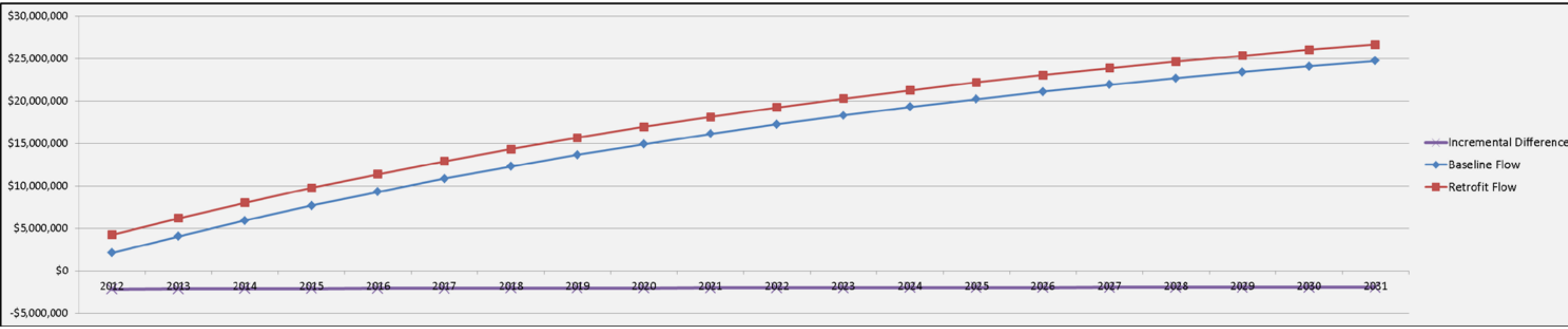
GSA can replicate these methods to estimate external cost of a building throughout its life cycle



Risk management can lead to lower discount rates and could help GSA account for non-traditional value

#	Risk Description	Level	Potential Mitigation Plans
1	Achieving a significant portion (up to half) of the energy savings will require occupant cooperation	High	- Engage occupants during analysis process via design charrettes/meetings - Thoroughly research installed technology and get user testimonials - Test improvements among certain groups before full rollout
2	Energy prices may be far greater or less than the expected increase	Med	- Conduct sensitivity analysis to understand how energy prices impact the financial return - Obtain long-term energy supply contract (e.g. a power purchase agreement) or technology
3	Predicted energy use is not equal to what was projected	High	- Use best-in-class predictive modeling (including peer reviews) - Create measurement & verification plan
6	Health costs have not decreased; employee productivity has not increased	High	- Ensure that the building occupants, their activities, and the implemented retrofit measures are similar to the referenced studies

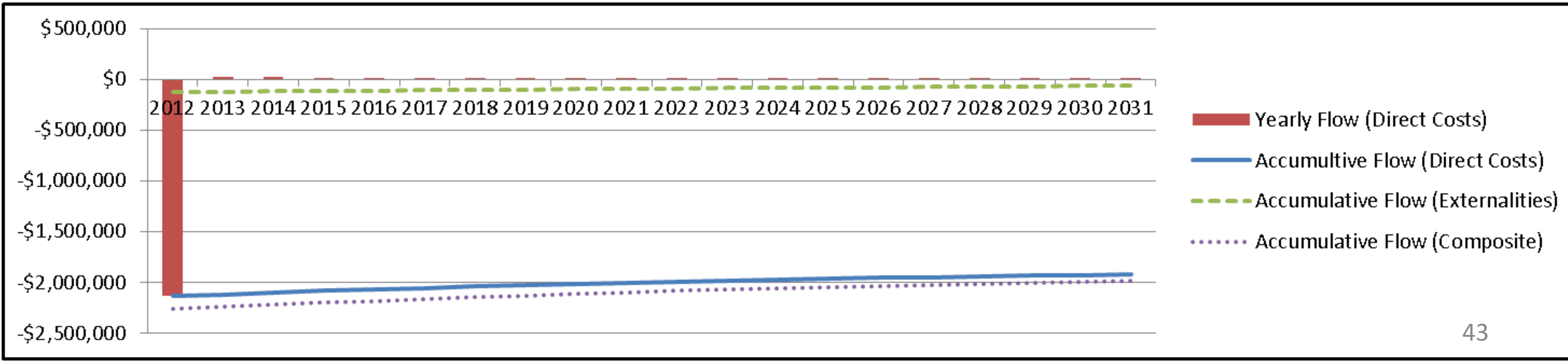
Measure 23: Deep Energy Retrofit, Windows - Fallon



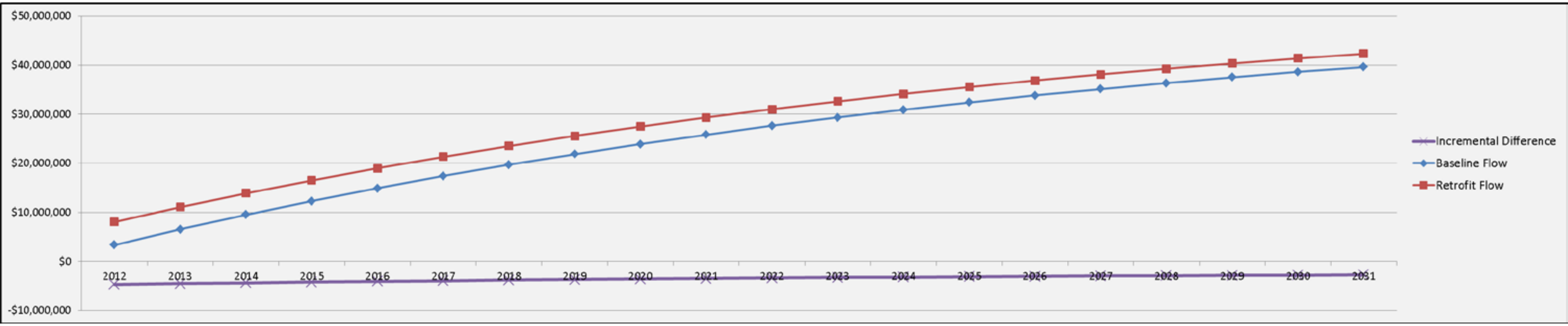
DER - Window Replacement			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$24,742,686	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$24,742,686	$9,270,675
	20 Year Retrofit Costs	Energy Costs	$24,524,709	
		Capital Costs	$2,140,128	
		O&M Costs	$0	
		Total	$26,664,836	$9,334,677
	Net Present Value (NPV)		($1,922,150)	($64,002)
	Composite NPV		($1,986,152)	

	Direct Costs	External Costs	Composite Costs
A. Deep Savings Budget ($ in NPV)	$12,567,038	$7,243,448	$19,810,486
B. Measure NPV ($)	($1,901,882)	($64,002)	($1,965,884)
C. Measure Installed Cost (2012 $ at Year 0)	$2,140,128	$127,115	$2,267,242
D. Remaining Budget (A - C)	$10,426,910	$7,116,333	$17,543,244
E. Percent of Budget (C/A)	17.03%	1.75%	11.4%

2.1% of Target Energy Savings, 17% of Budget



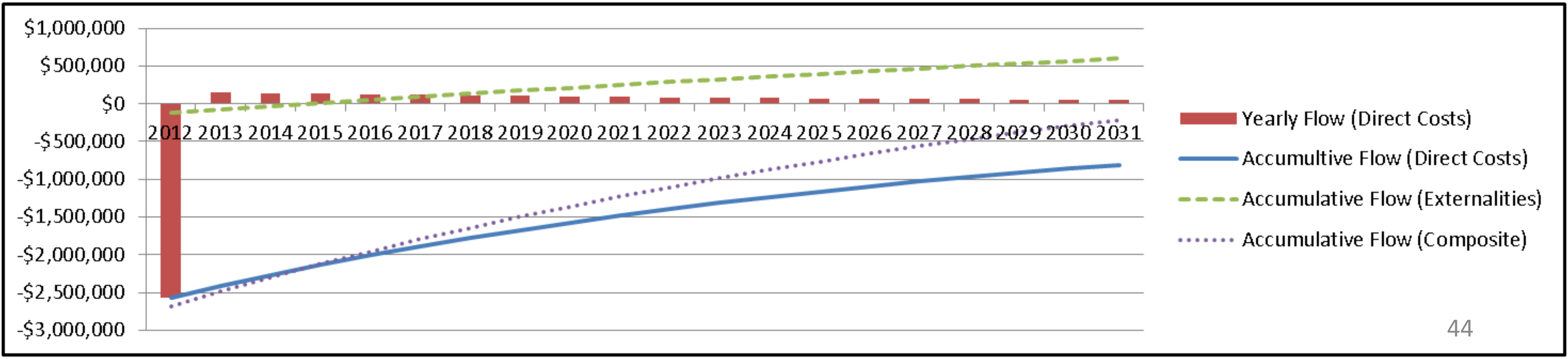
Garmatz Deep Savings – Window Analysis



DER - Garmatz Windows			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$14,879,407	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$14,879,407	$7,074,125
	20 Year Retrofit Costs	Energy Costs	$13,122,692	
		Capital Costs	$2,567,350	
		O&M Costs	$0	
		Total	$15,690,042	$6,474,419
	Net Present Value (NPV)		($810,636)	$599,706
	Composite NPV		($210,930)	

	Direct Costs	External Costs	Composite Costs
A. Deep Savings Budget ($ in NPV)	$8,119,317	$4,559,609	$12,678,926
B. Measure NPV ($)	($810,636)	$599,706	($210,930)
C. Measure Installed Cost (2012 $ at Year 0)	$2,567,350	$113,669	$2,681,019
D. Remaining Budget (A - C)	$5,551,967	$4,445,940	$9,997,907
E. Percent of Budget (C/A)	31.6%	2.5%	21.1%

31.4% of Target Energy Savings, 31.6% of Budget



Potential Next Steps

- **Seeking a “business as usual” project to include LCA**
  - Feasibility Study
  - BER
  - Energy Audit
  - Etc.
- **Collaboration Across Regions**
- **National Sustainability Council FY13 PT Goal**
- **Begin looking at emissions reporting as a procurement factor**
  - In support of the Federal Vendor and Contractor Sustainability Considerations pilot program

Conclusions and Recommendations

Feedback?

Questions?

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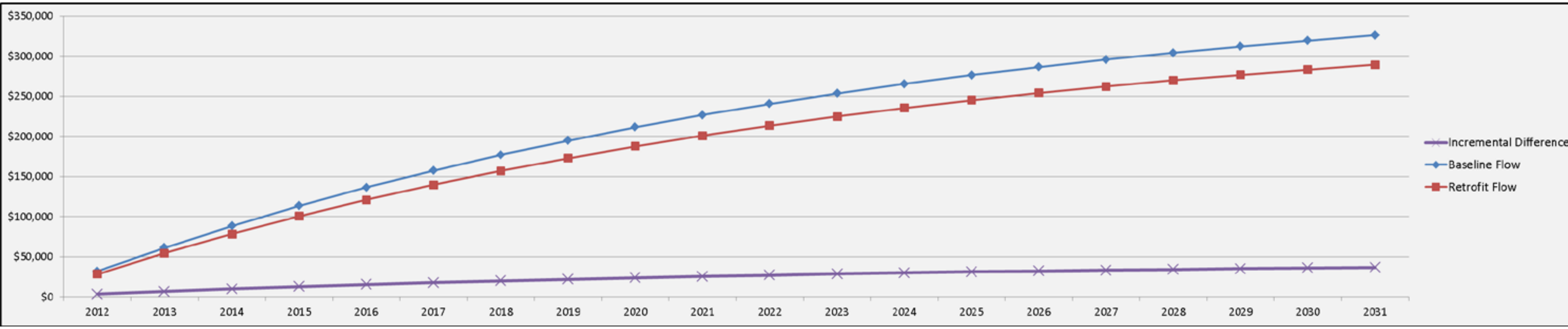
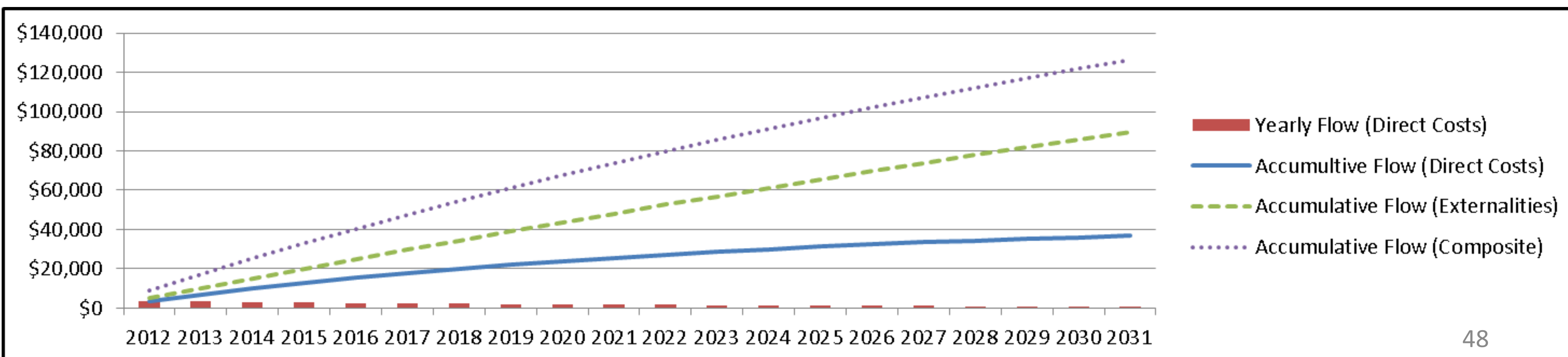
Chris Mattingly – christopher.mattingly@gsa.gov

Measures 1 - 24

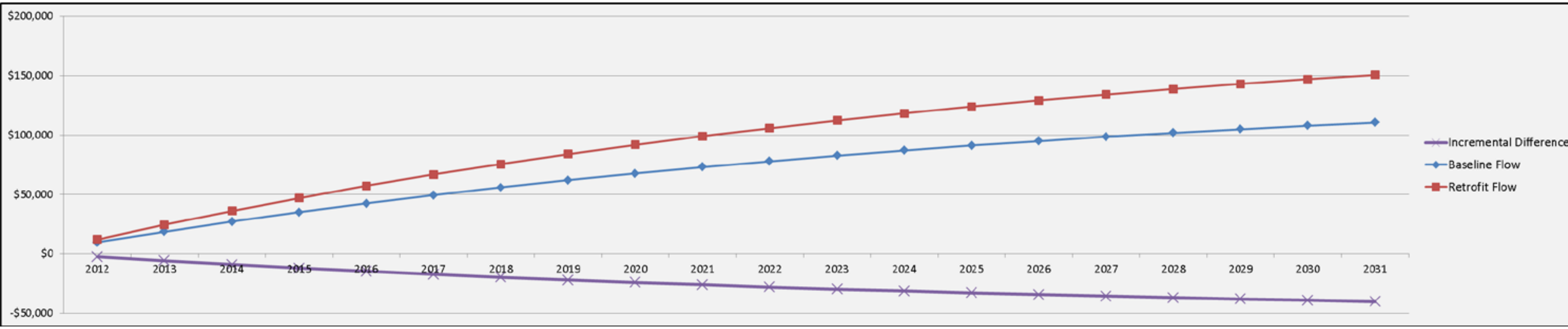
Measure 1: Solid Waste Management - General



			Direct Costs	External Costs
Solid Waste	20 Year Baseline Costs	Energy Costs	$0	
		Capital Costs	$0	
		O&M Costs	$326,151	
		Total	$326,151	$11,230
	20 Year Retrofit Costs	Energy Costs	$0	
		Capital Costs	$0	
		O&M Costs	$289,341	
		Total	$289,341	($78,395)
	Net Present Value (NPV)		**$36,810**	**$89,625**
	Composite NPV		**$126,435**	



Measure 2: Indoor Air Quality - General



External Costs:

Energy = $0.02/ft^2$

Productivity = $(1.52/ft^2)$

Area = 36,453 ft^2

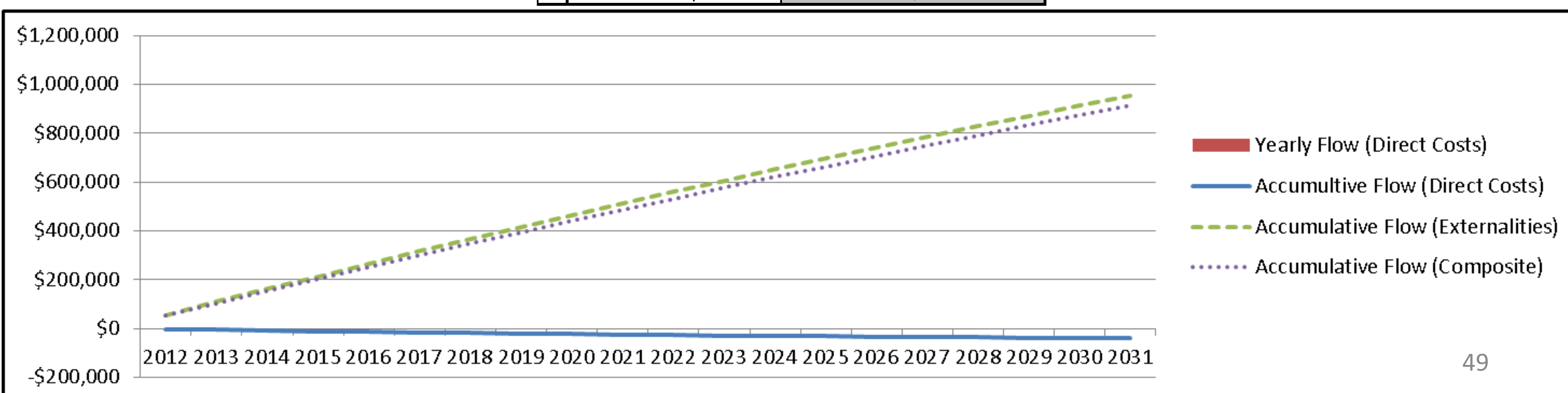
IAQ			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$90,460	
		Capital Costs	$0	
		O&M Costs	$20,216	
		Total	$110,675	$32,191
	20 Year Retrofit Costs	Energy Costs	$120,755	
		Capital Costs	$1,609	
		O&M Costs	$28,355	
		Total	$150,719	($921,442)
	Net Present Value (NPV)		**($40,043)**	**$953,633**
	Composite NPV		**$913,590**	

Annual Incremental Costs:

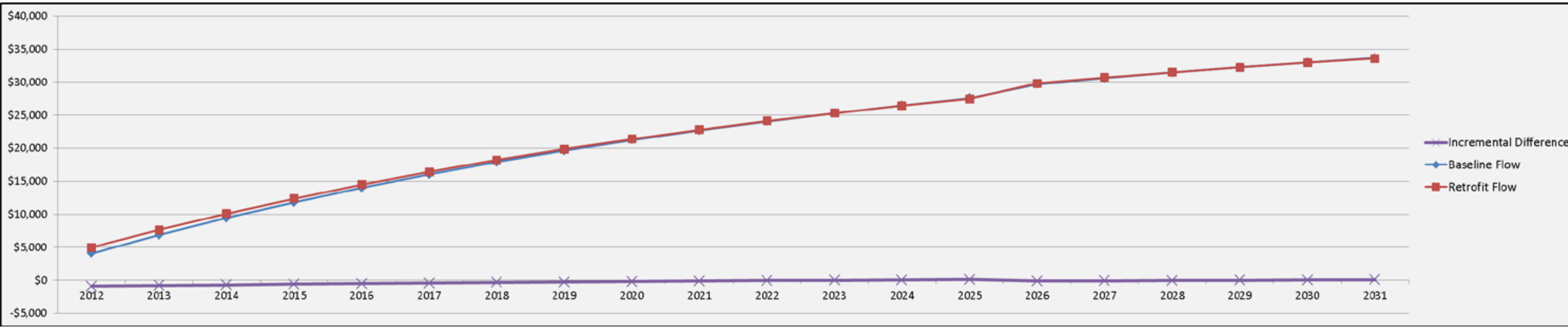
Direct Cost = $798

External Cost = ($51,030)

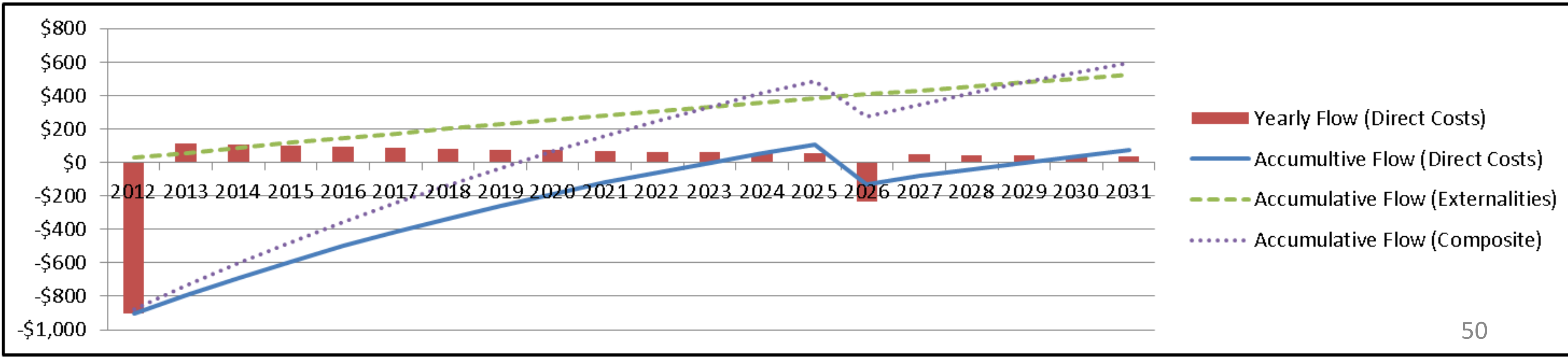
Net Cost = ($50,232)



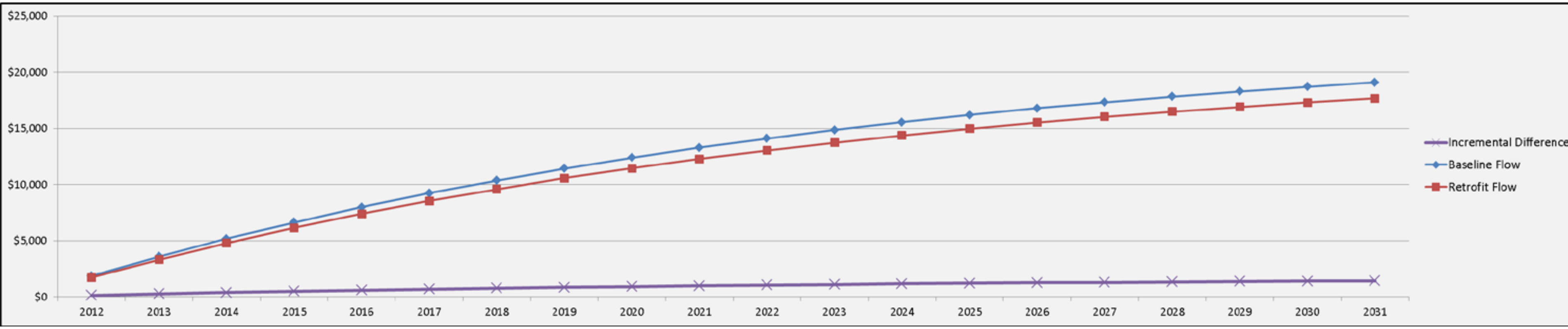
Measure 3: Refrigerant Management - General



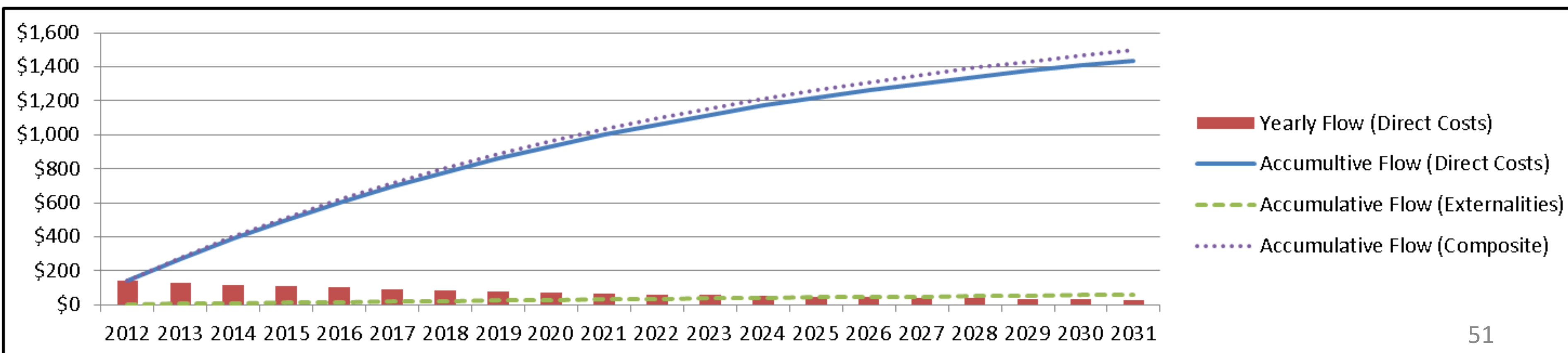
Refrigerant Management			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$5,972	
		Capital Costs	$4,699	
		O&M Costs	$22,999	
		Total	$33,670	$2,358
	20 Year Retrofit Costs	Energy Costs	$4,712	
		Capital Costs	$5,886	
		O&M Costs	$22,999	
		Total	$33,597	$1,836
	Net Present Value (NPV)		**$74**	**$523**
	Composite NPV		**$596**	



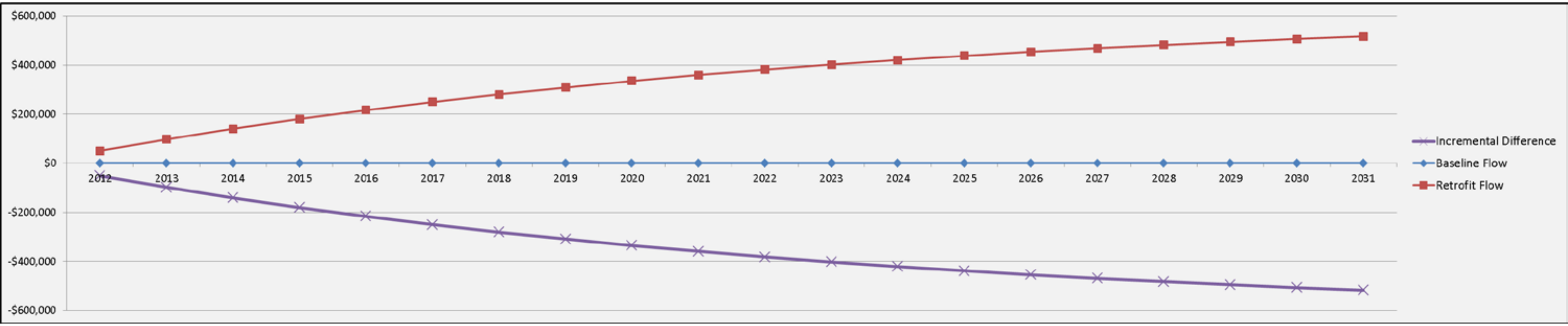
Measure 4: Green Cleaning - General



Green Cleaning Products			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$0	
		Capital Costs	$0	
		O&M Costs	$19,114	
		Total	$19,114	$434
	20 Year Retrofit Costs	Energy Costs	$0	
		Capital Costs	$0	
		O&M Costs	$17,676	
		Total	$17,676	$374
	Net Present Value (NPV)		**$1,438**	**$60**
	Composite NPV		**$1,498**	



Measure 5: Transportation - General (1 of 2)



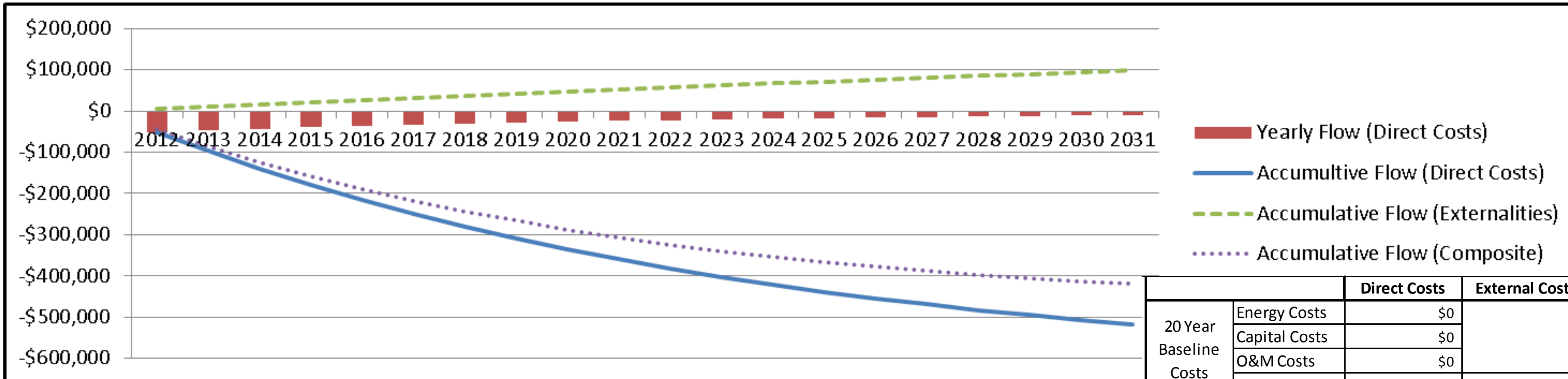
Baseline assumes GSA pays for Train Passes

Proposed = 2 Scenarios:

1. No cost for Building Occupant Gasoline Cost included
2. Cost for Building Occupant Gasoline Cost shown as External Cost

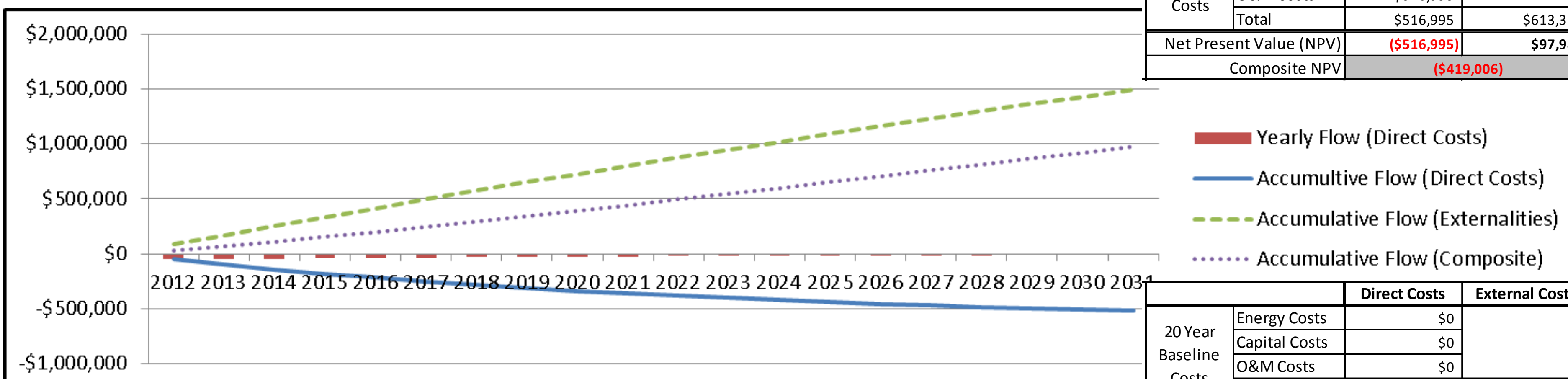
Measure 5: Transportation - General (2 of 2)

Scenario 1: Gasoline Costs Excluded



		Direct Costs	External Costs
20 Year Baseline Costs	Energy Costs	$0	
	Capital Costs	$0	
	O&M Costs	$0	
	Total	$0	$711,299
20 Year Retrofit Costs	Energy Costs	$0	
	Capital Costs	$0	
	O&M Costs	$516,995	
	Total	$516,995	$613,310
Net Present Value (NPV)		($516,995)	$97,989
Composite NPV		($419,006)	

Scenario 2: Gasoline Costs Included



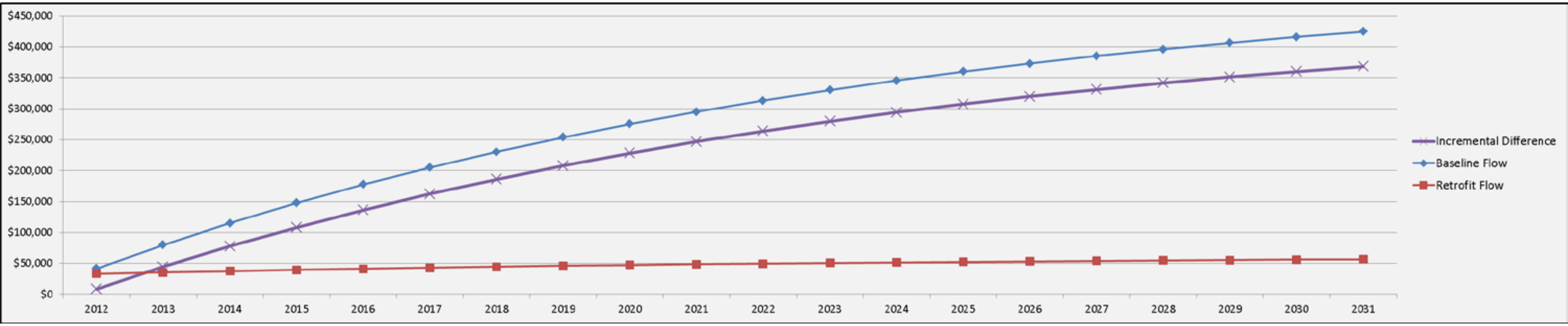
		Direct Costs	External Costs
20 Year Baseline Costs	Energy Costs	$0	
	Capital Costs	$0	
	O&M Costs	$0	
	Total	$0	$2,107,170
20 Year Retrofit Costs	Energy Costs	$0	
	Capital Costs	$0	
	O&M Costs	$516,995	
	Total	$516,995	$613,310
Net Present Value (NPV)		($516,995)	$1,493,860
Composite NPV		$976,865	

Baseline External Costs:

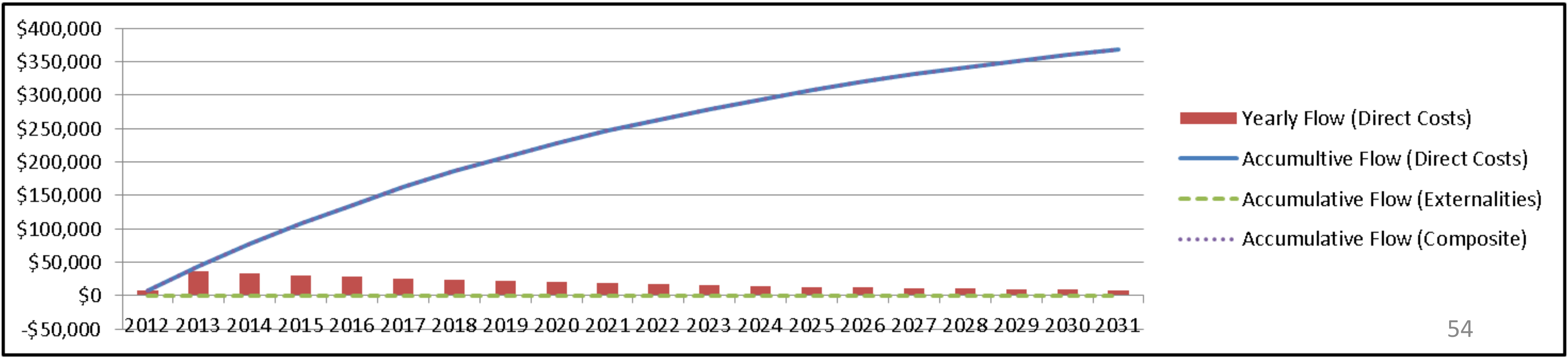
Scenario 1 = $ 40,812

Scenario 2 = $120,920 (includes $80,102 for gasoline)

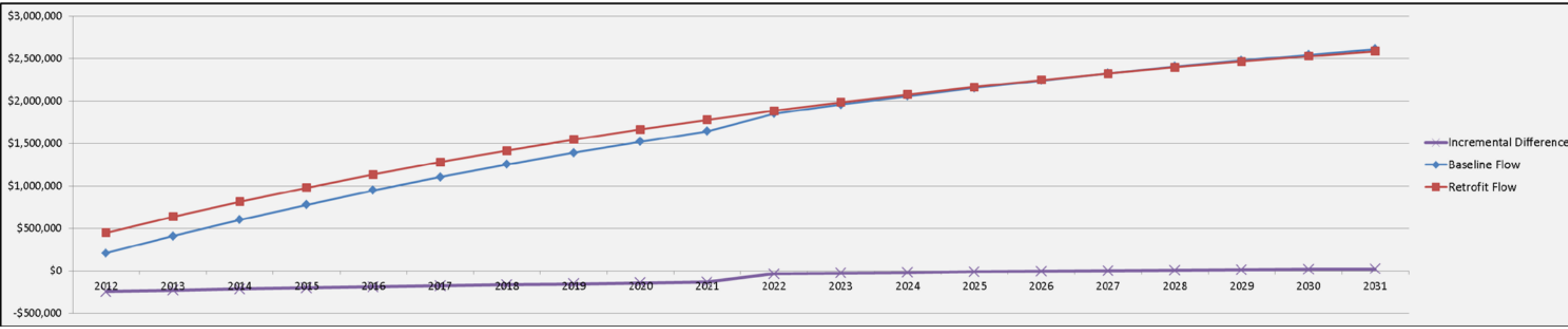
Measure 6: Landscaping - General



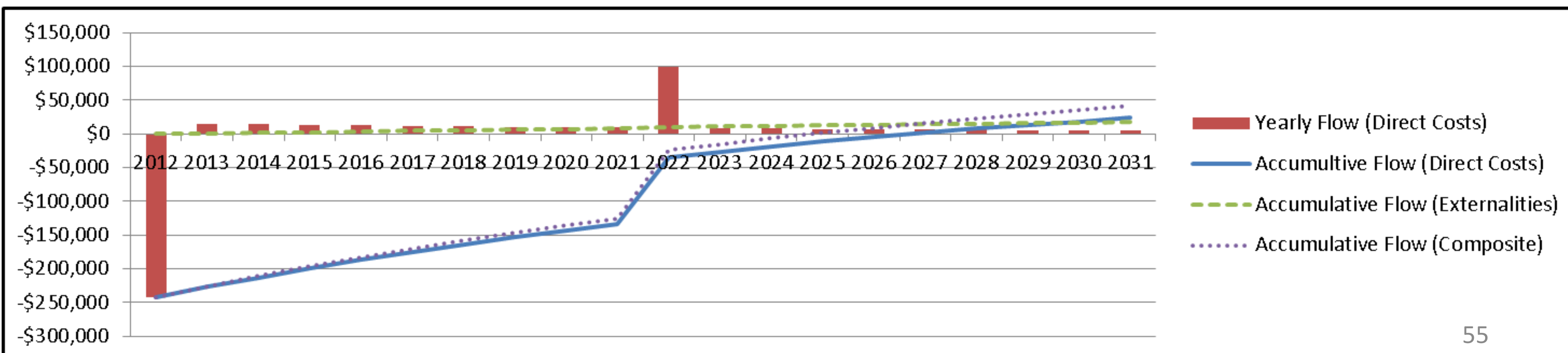
Landscaping			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$5,148	
		Capital Costs	$331,200	
		O&M Costs	$88,440	
		Total	$424,788	$69
	20 Year Retrofit Costs	Energy Costs	$2,511	
		Capital Costs	$30,380	
		O&M Costs	$23,559	
		Total	$56,450	$39
	Net Present Value (NPV)		**$368,338**	**$30**
	Composite NPV		**$368,369**	



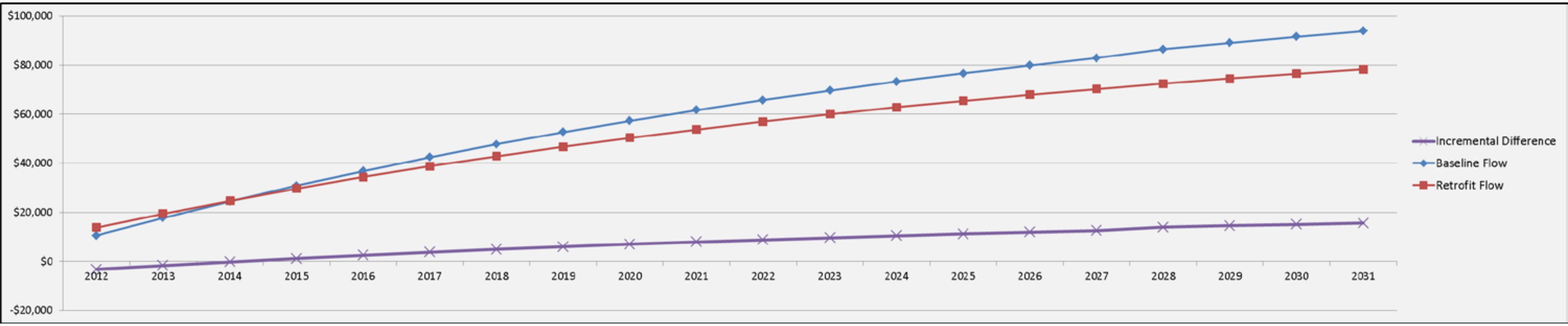
Measure 7: Indoor Water Use - Garmatz



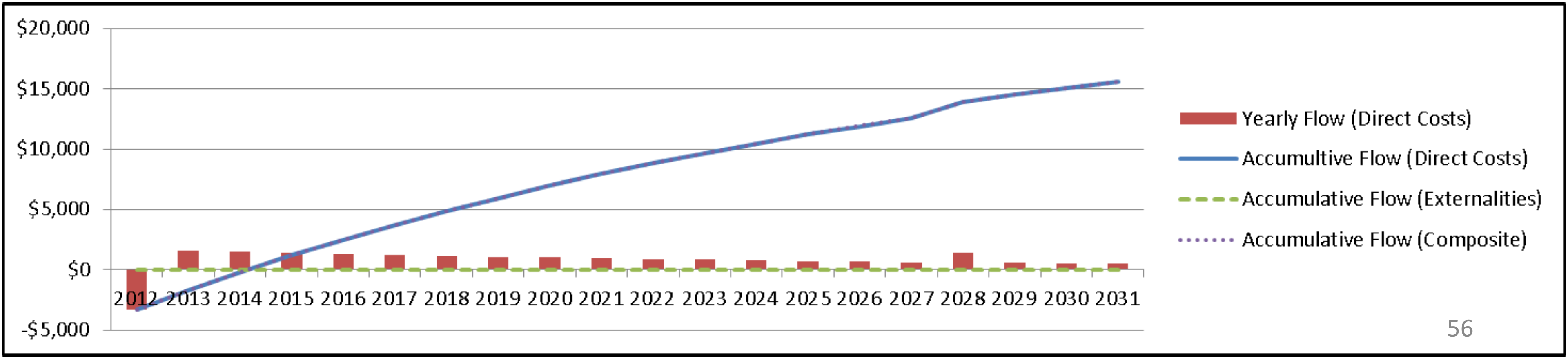
Interior Water Use Reductions			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$2,438,223	
		Capital Costs	$90,668	
		O&M Costs	$84,031	
		Total	$2,612,922	$823,386
	20 Year Retrofit Costs	Energy Costs	$2,256,432	
		Capital Costs	$242,073	
		O&M Costs	$90,971	
		Total	$2,589,476	$805,680
	Net Present Value (NPV)		**$23,446**	**$17,707**
	Composite NPV		**$41,153**	



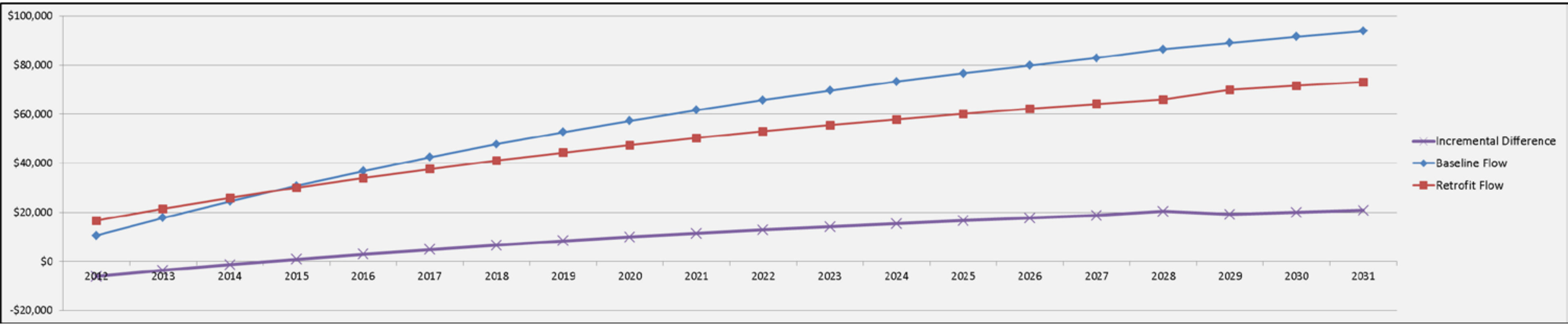
Measure 8: Mercury in Lighting, T8 XLL - General (1 of 2)



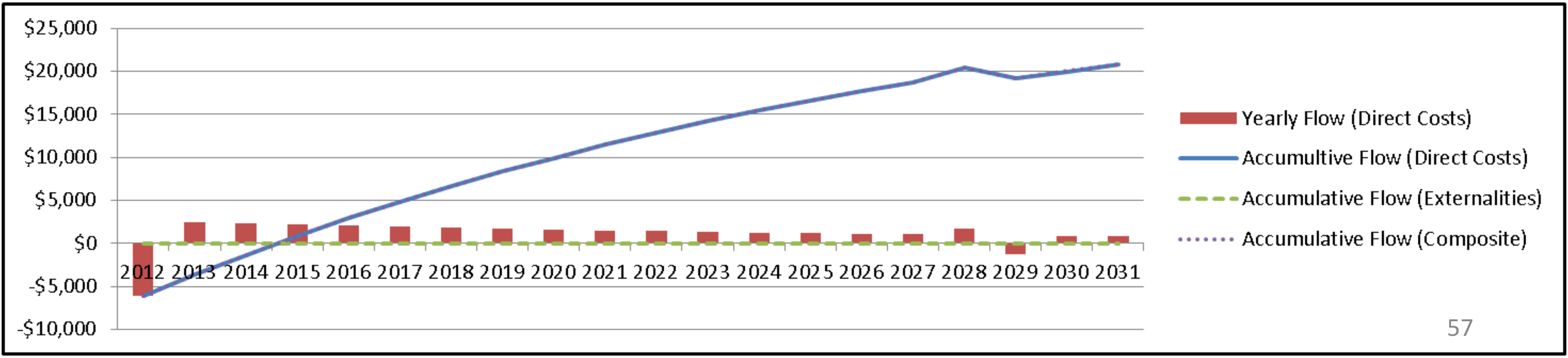
Mercury in Lighting			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$90,278	
		Capital Costs	$3,611	
		O&M Costs	$0	
		Total	$93,888	$19
	20 Year Retrofit Costs	Energy Costs	$72,209	
		Capital Costs	$6,110	
		O&M Costs	$0	
		Total	$78,319	$14
	Net Present Value (NPV)		**$15,569**	**$6**
	Composite NPV		**$15,575**	



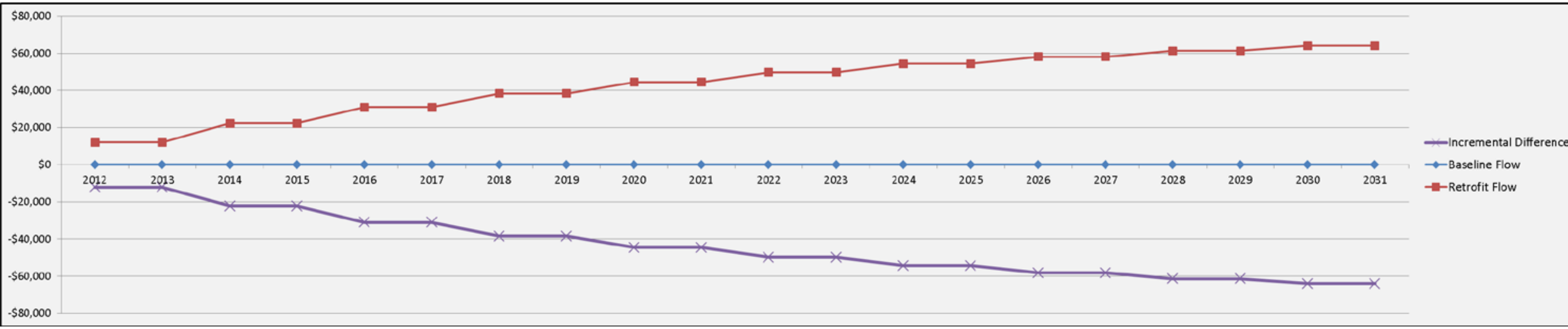
Measure 8: Mercury in Lighting, T5 - General (2 of 2)



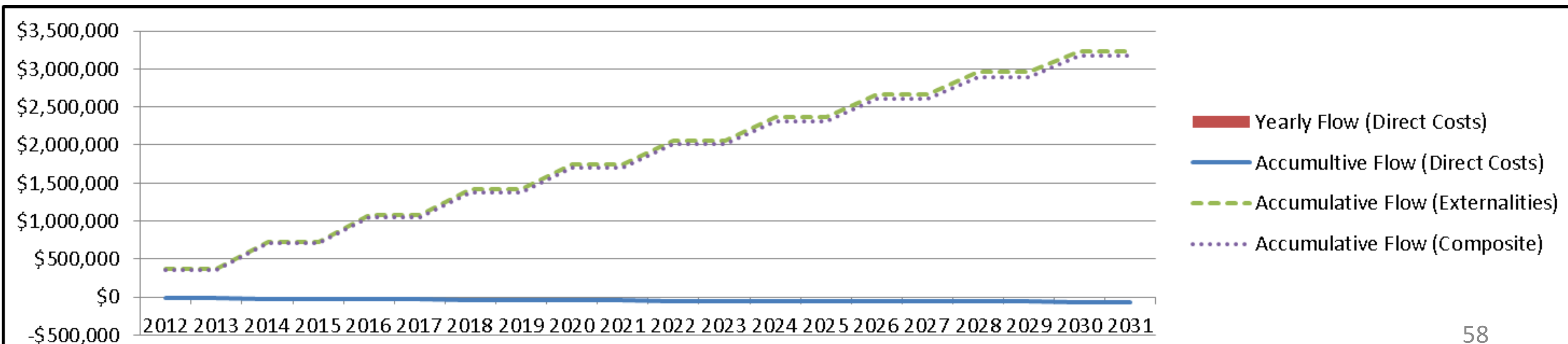
Mercury in Lighting			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$90,278	
		Capital Costs	$3,611	
		O&M Costs	$0	
		Total	$93,888	$19
	20 Year Retrofit Costs	Energy Costs	$61,885	
		Capital Costs	$11,212	
		O&M Costs	$0	
		Total	$73,097	$14
	Net Present Value (NPV)		**$20,792**	**$5**
	Composite NPV		**$20,797**	



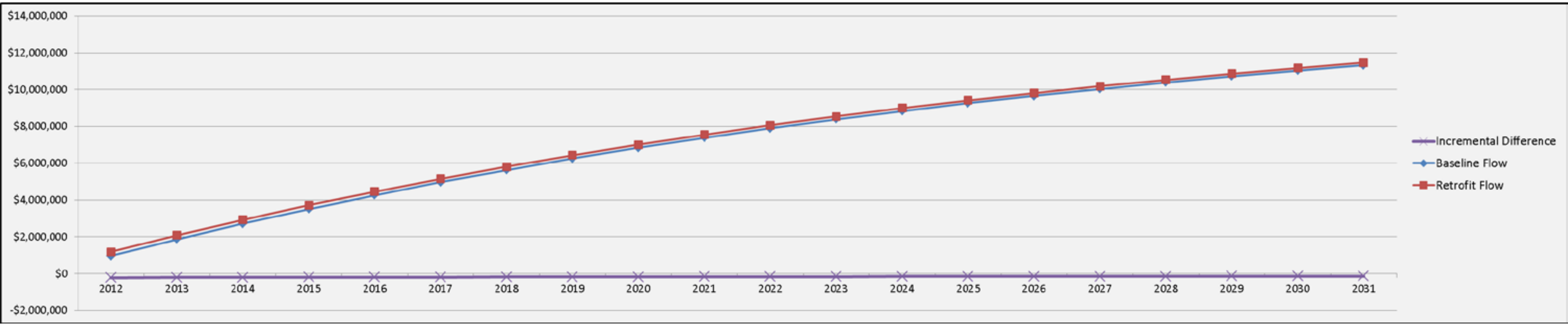
Measure 9: Renewable Energy Credits - Garmatz



			Direct Costs	External Costs
Renewable Energy Credits	20 Year Baseline Costs	Energy Costs	$0	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$0	$0
	20 Year Retrofit Costs	Energy Costs	$0	
		Capital Costs	$64,090	
		O&M Costs	$0	
		Total	$64,090	($3,239,106)
	Net Present Value (NPV)		**($64,090)**	**$3,239,106**
	Composite NPV		**$3,175,016**	

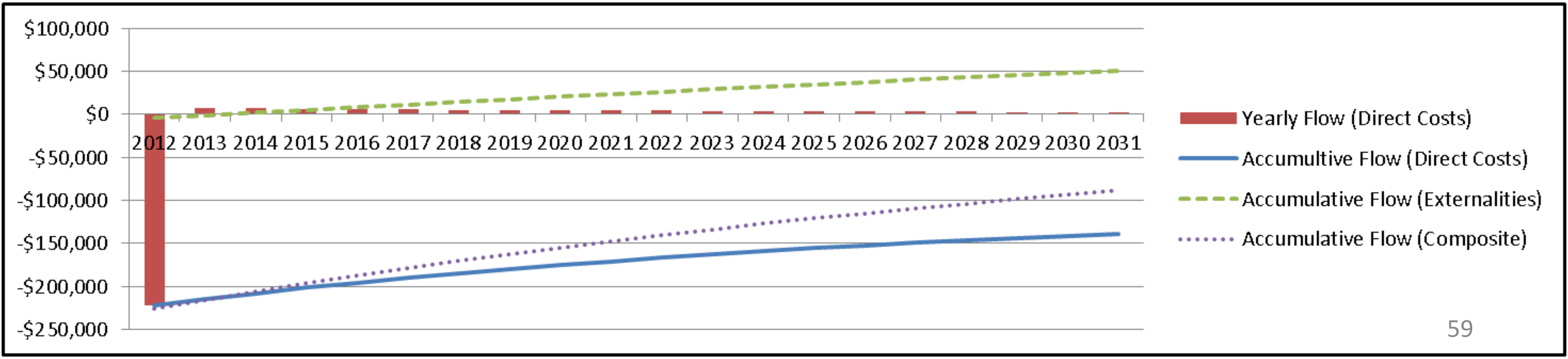


Measure 10: Photovoltaics - Fallon

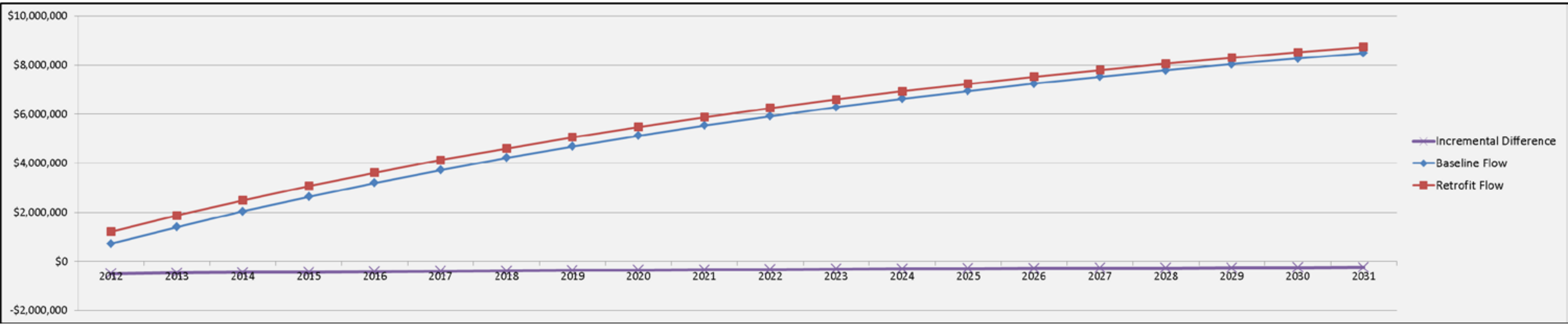


On site Renewable Energy

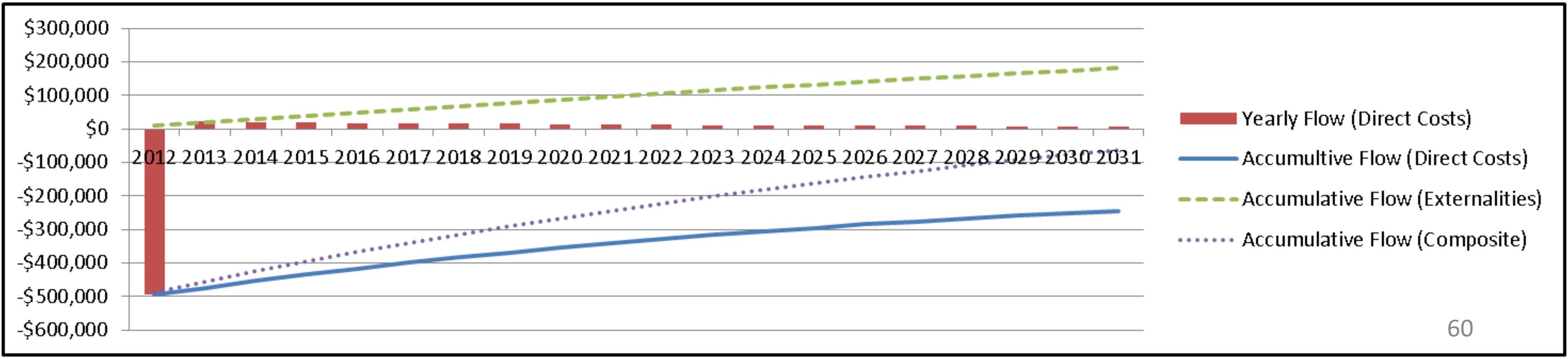
		Direct Costs	**External Costs**
20 Year Baseline Costs	Energy Costs	$11,327,571	
	Capital Costs	$0	
	O&M Costs	$0	
	Total	$11,327,571	$0
20 Year Retrofit Costs	Energy Costs	$11,239,140	
	Capital Costs	$222,000	
	O&M Costs	$5,630	
	Total	$11,466,770	($50,447)
Net Present Value (NPV)		**($139,199)**	**$50,447**
Composite NPV		**($88,752)**	



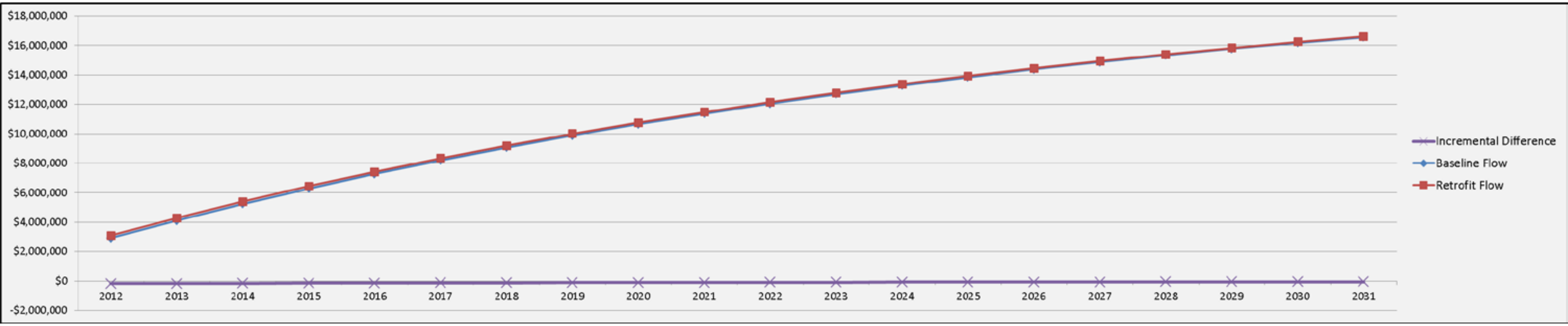
Measure 11: Co-Generate Electricity - Garmatz



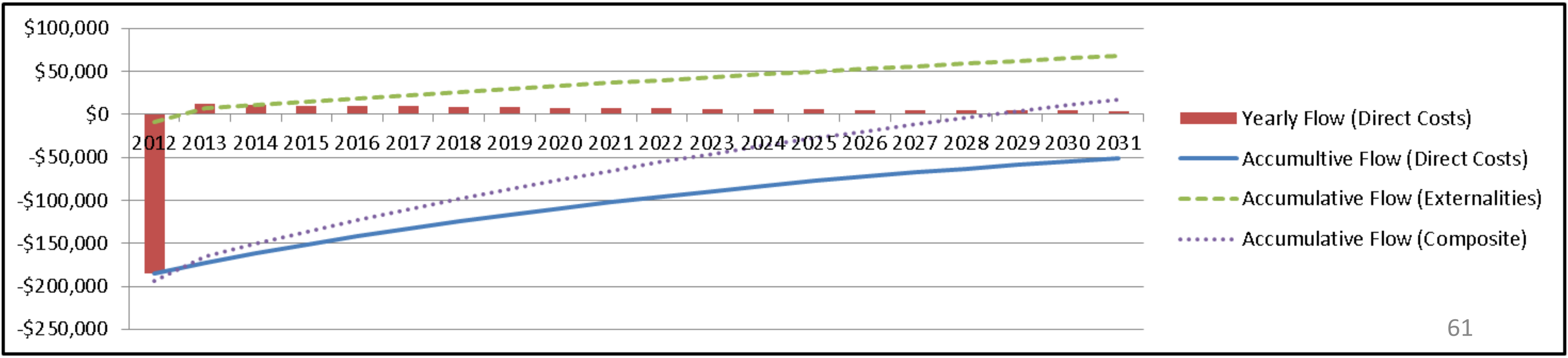
Co-Generate Electricity			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$8,491,729	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$8,491,729	$6,817,572
	20 Year Retrofit Costs	Energy Costs	$8,216,387	
		Capital Costs	$495,000	
		O&M Costs	$23,919	
		Total	$8,735,306	$6,635,547
	Net Present Value (NPV)		($243,577)	**$182,025**
	Composite NPV		($61,552)	



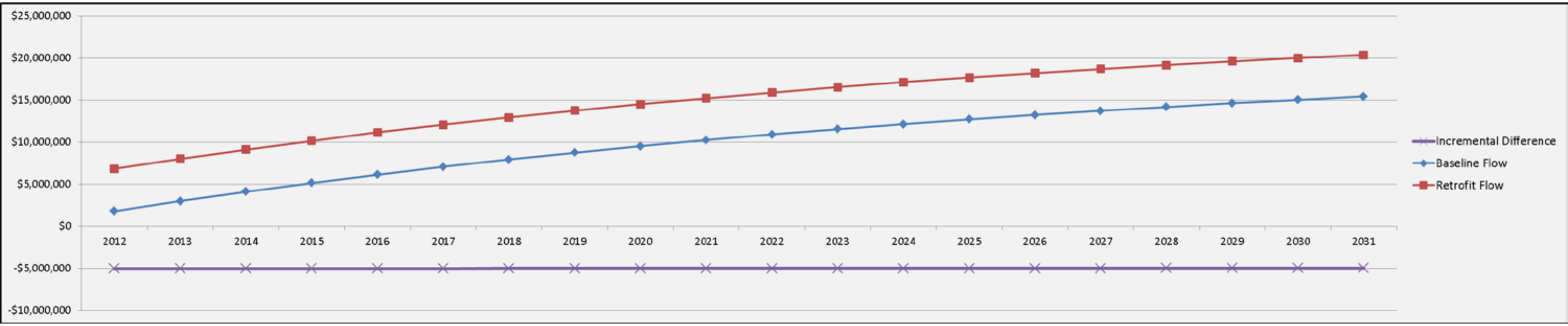
Measure 12: Replace Air Handling Units - Garmatz



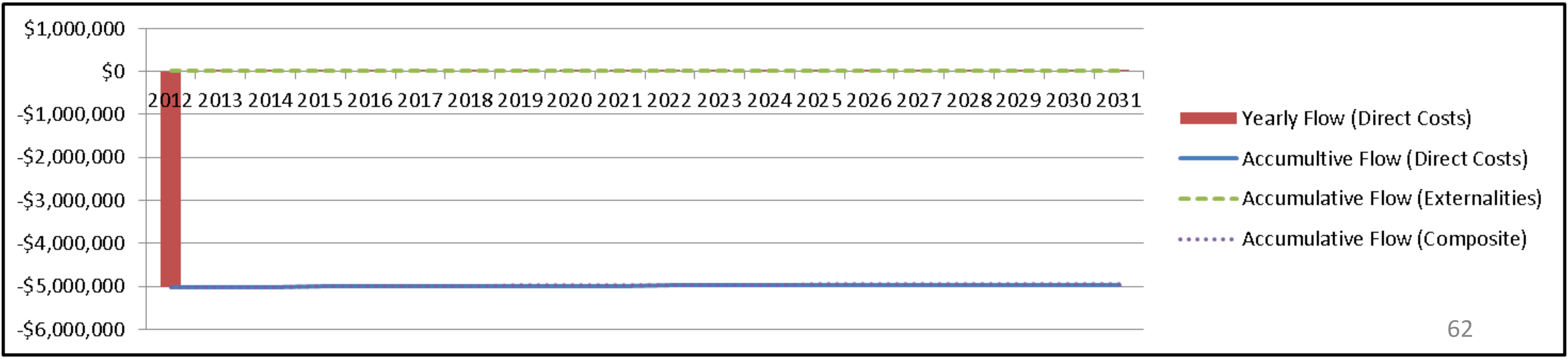
AHU Replacement			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$14,879,407	
		Capital Costs	$1,652,196	
		O&M Costs	$36,798	
		Total	$16,568,401	$6,830,856
	20 Year Retrofit Costs	Energy Costs	$14,738,417	
		Capital Costs	$1,836,708	
		O&M Costs	$44,158	
		Total	$16,619,283	$6,762,620
	Net Present Value (NPV)		**($50,882)**	**$68,236**
	Composite NPV		**$17,354**	



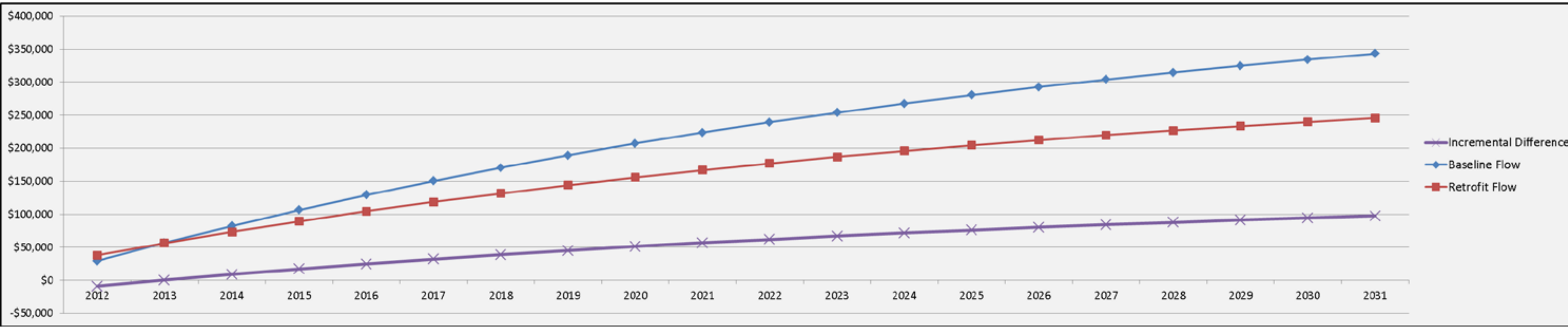
Measure 13: Cool Roof - Garmatz



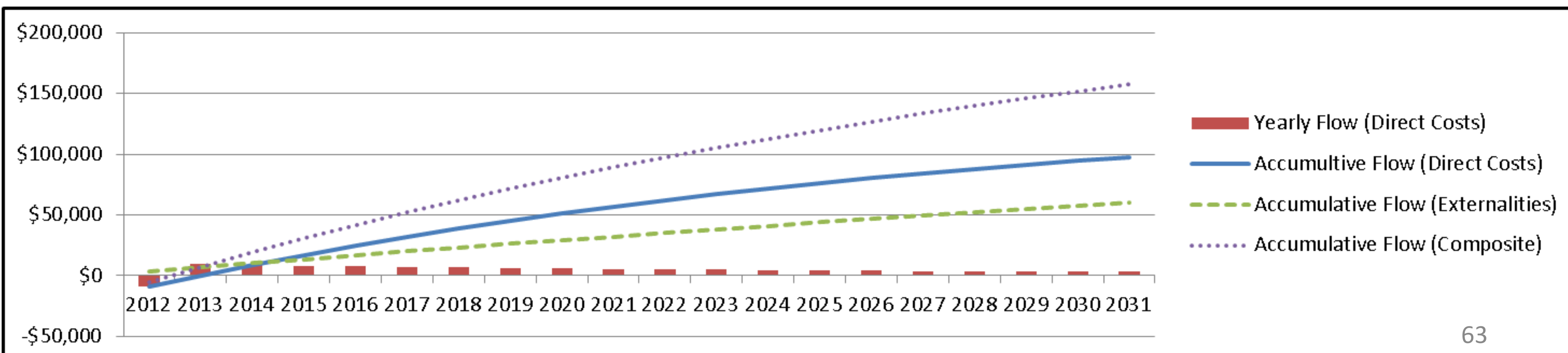
			Direct Costs	External Costs
Cool Roofs	20 Year Baseline Costs	Energy Costs	$14,879,407	
		Capital Costs	$547,139	
		O&M Costs	$0	
		Total	$15,426,546	$5,863,940
	20 Year Retrofit Costs	Energy Costs	$14,814,940	
		Capital Costs	$5,574,111	
		O&M Costs	$0	
		Total	$20,389,051	$5,840,661
	Net Present Value (NPV)		**($4,962,505)**	**$23,279**
	Composite NPV		**($4,939,227)**	



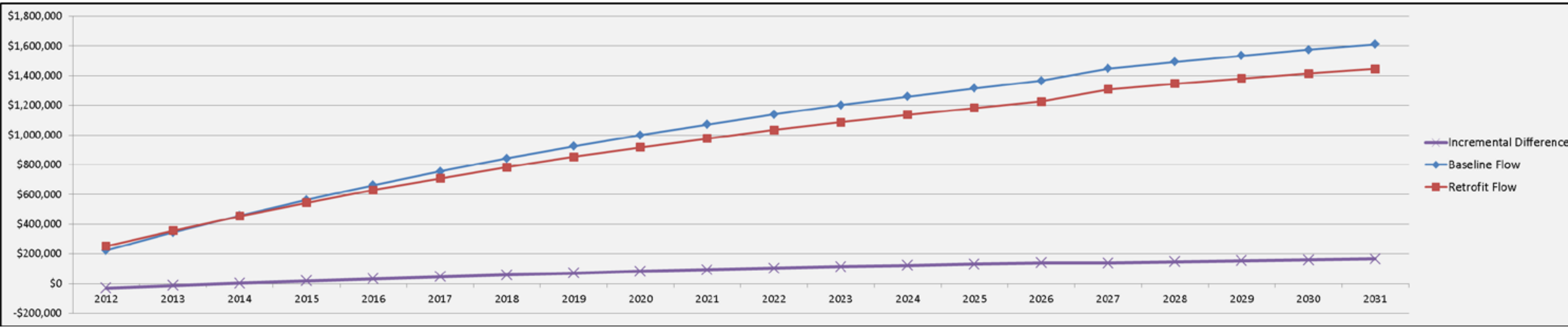
Measure 14: Reduce Plug Loads - Garmatz



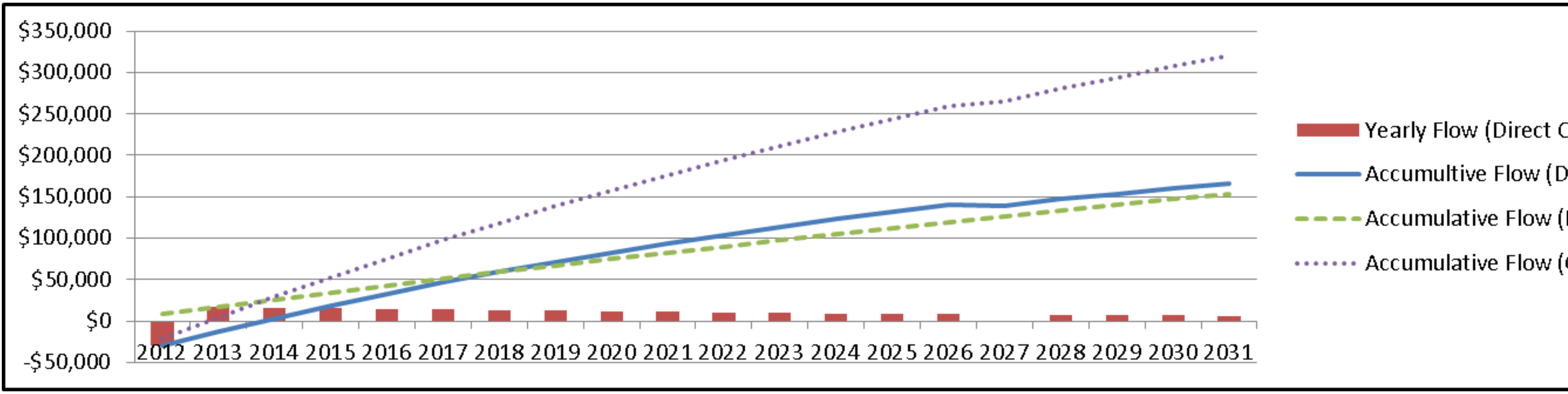
Reduce Plug Loads			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$343,169	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$343,169	$168,892
	20 Year Retrofit Costs	Energy Costs	$231,753	
		Capital Costs	$8,879	
		O&M Costs	$5,060	
		Total	$245,691	$108,959
	Net Present Value (NPV)		**$97,478**	**$59,933**
	Composite NPV		**$157,410**	



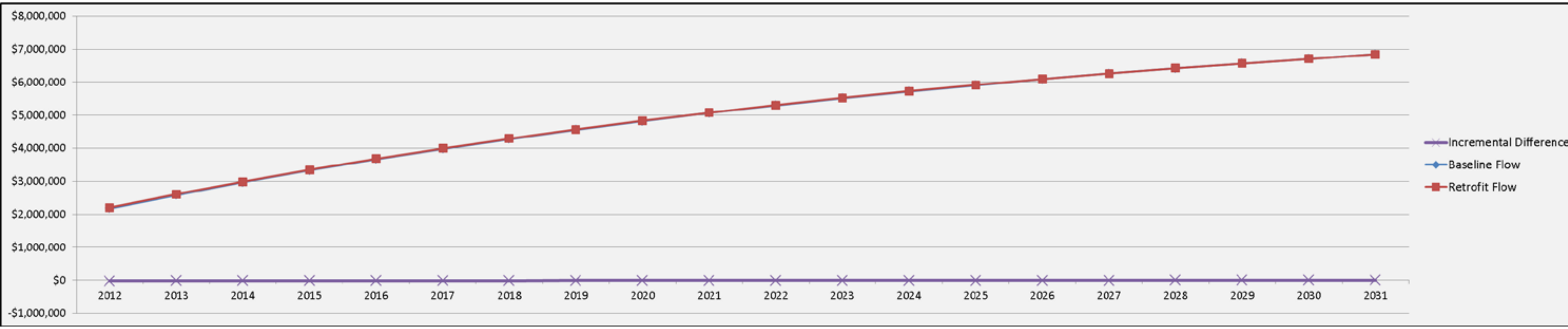
Measure 15: Lighting Retrofits - Garmatz



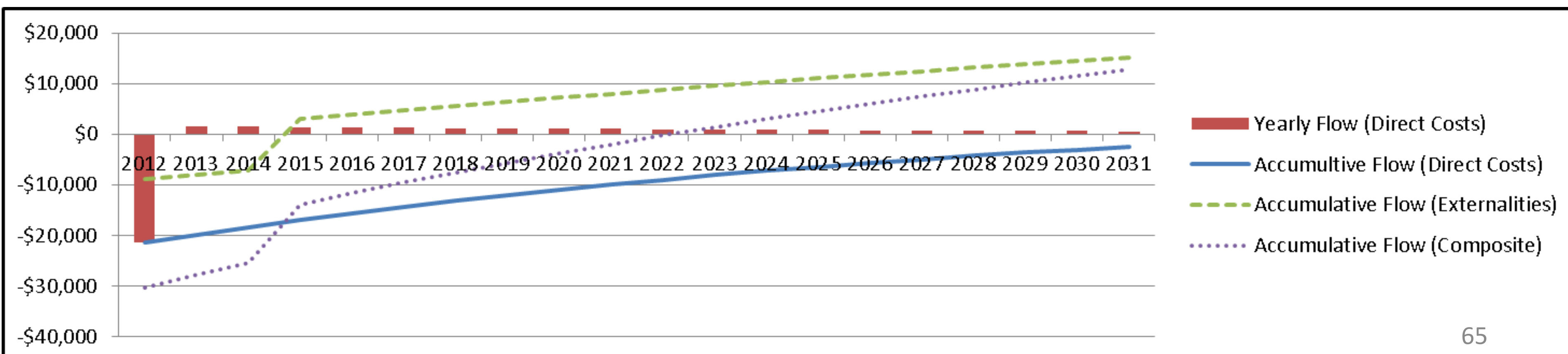
Lighting Retrofits			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$1,256,433	
		Capital Costs	$150,029	
		O&M Costs	$205,033	
		Total	$1,611,494	$618,358
	20 Year Retrofit Costs	Energy Costs	$971,069	
		Capital Costs	$188,055	
		O&M Costs	$285,744	
		Total	$1,444,868	$464,857
	Net Present Value (NPV)		**$166,627**	**$153,501**
	Composite NPV		**$320,128**	



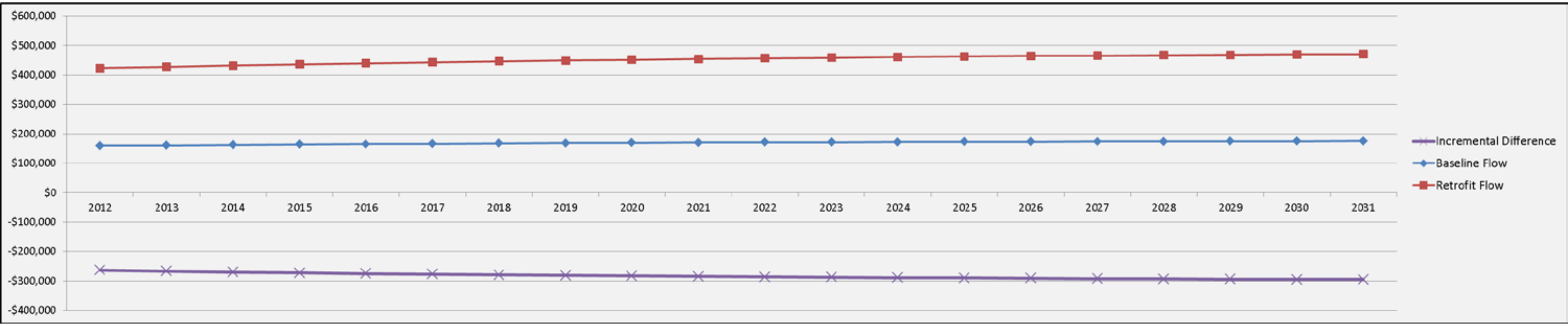
Measure 16: Replace Air Handling Units - CH



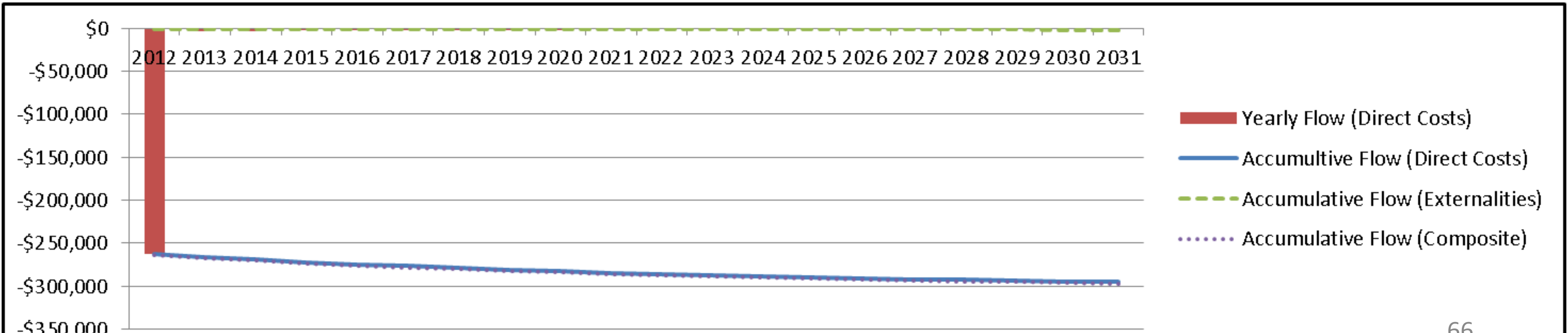
Replace the (7) Air Handling Units			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$5,056,244	
		Capital Costs	$1,750,681	
		O&M Costs	$32,198	
		Total	$6,839,124	$2,013,931
	20 Year Retrofit Costs	Energy Costs	$5,030,804	
		Capital Costs	$1,772,164	
		O&M Costs	$38,638	
		Total	$6,841,606	$1,998,702
	Net Present Value (NPV)		($2,482)	**$15,229**
	Composite NPV		**$12,746**	



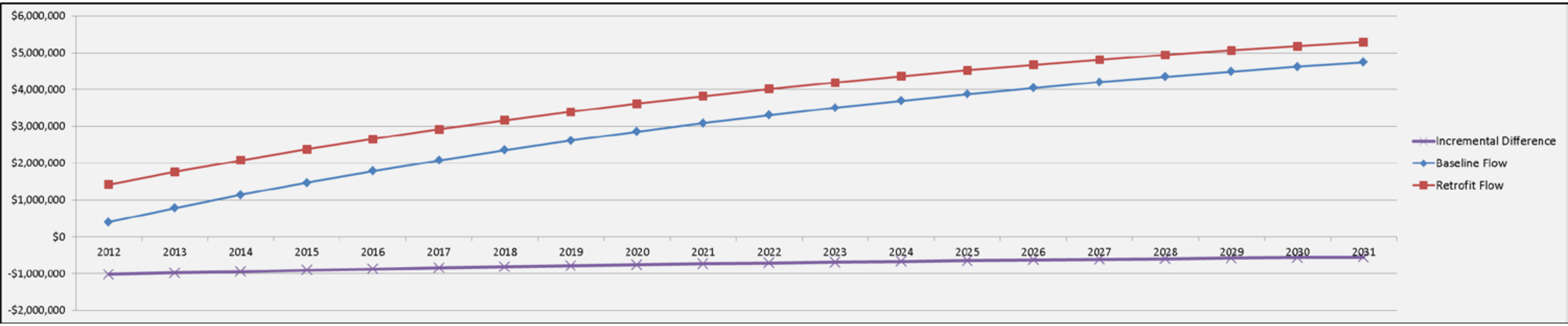
Measure 17: Green Roof - Custom House



Green Roof			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$0	
		Capital Costs	$159,211	
		O&M Costs	$15,865	
		Total	$175,076	$2,009,853
	20 Year Retrofit Costs	Energy Costs	$0	
		Capital Costs	$422,411	
		O&M Costs	$48,071	
		Total	$470,481	$2,011,570
	Net Present Value (NPV)		($295,405)	($1,717)
	Composite NPV		($297,122)	

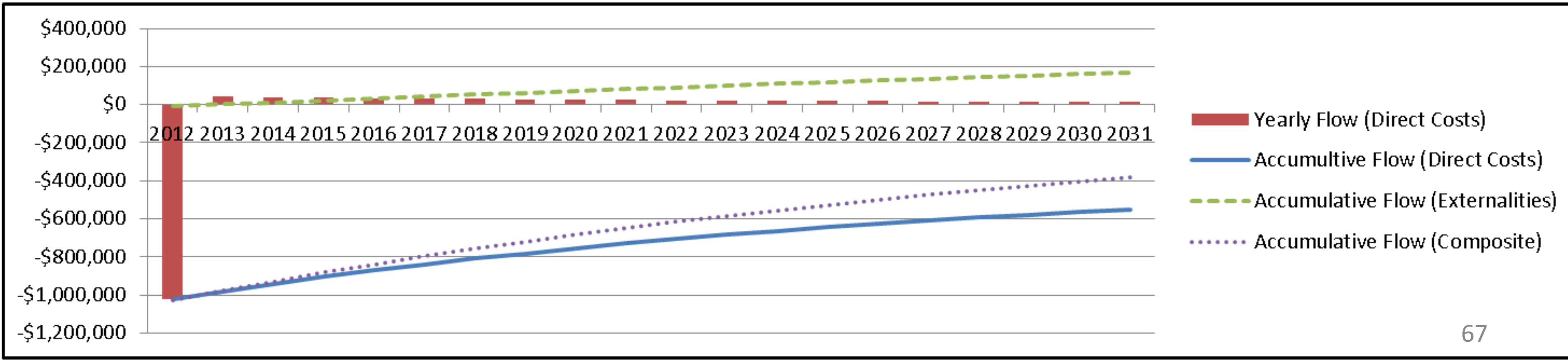


Measure 18: Replace Windows – Custom House (1 of 2)

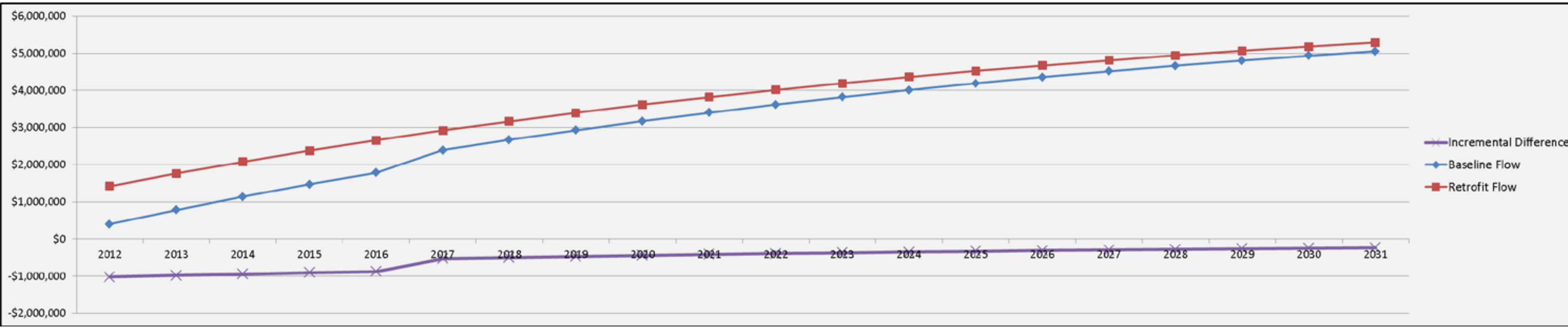


Scenario 1: No window replacement in Baseline

Replace Windows			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$4,741,663	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$4,741,663	$1,745,527
	20 Year Retrofit Costs	Energy Costs	$4,270,621	
		Capital Costs	$1,021,844	
		O&M Costs	$0	
		Total	$5,292,465	$1,577,331
	Net Present Value (NPV)		($550,802)	$168,196
	Composite NPV		($382,606)	

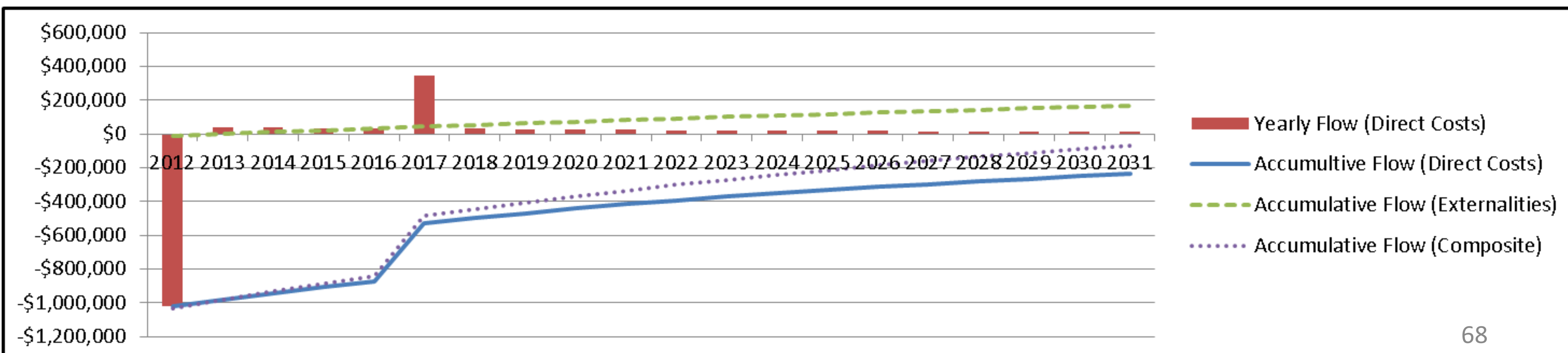


Measure 18: Replace Windows – Custom House (2 of 2)

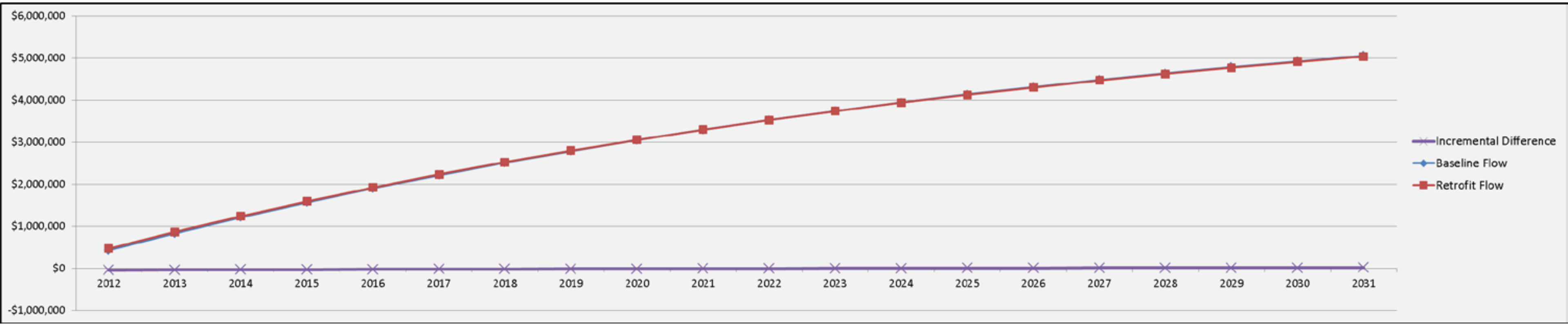


Scenario 2: Window replacement in Baseline at Year 5

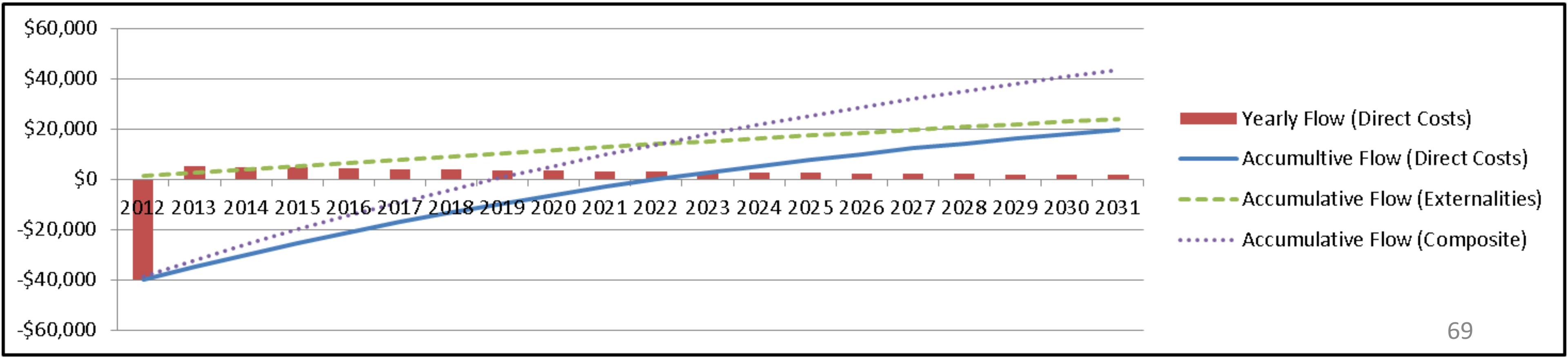
			Direct Costs	External Costs
Replace Windows	20 Year Baseline Costs	Energy Costs	$4,741,663	
		Capital Costs	$313,843	
		O&M Costs	$0	
		Total	$5,055,506	$1,746,099
	20 Year Retrofit Costs	Energy Costs	$4,270,621	
		Capital Costs	$1,021,844	
		O&M Costs	$0	
		Total	$5,292,465	$1,577,422
	Net Present Value (NPV)		($236,959)	$168,677
	Composite NPV		($68,282)	



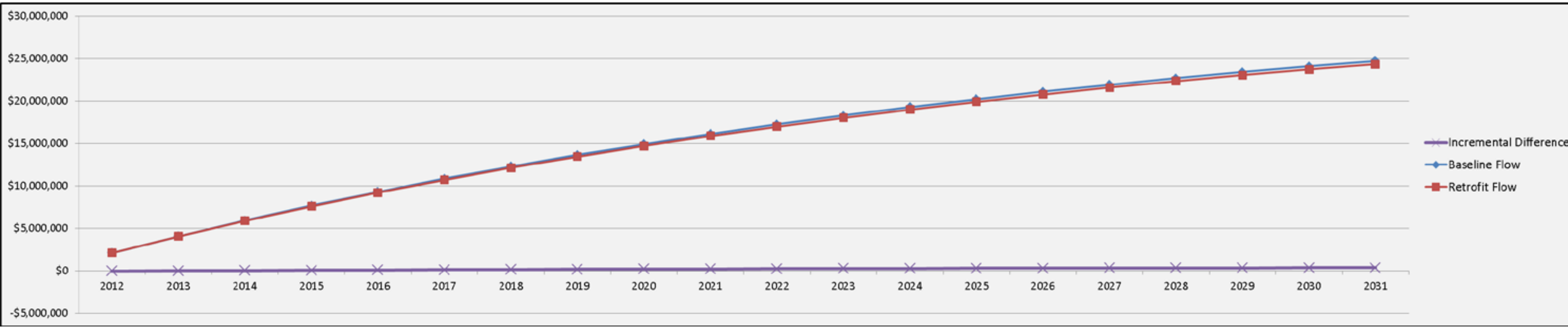
Measure 19: Install Heat Pipe - Custom House



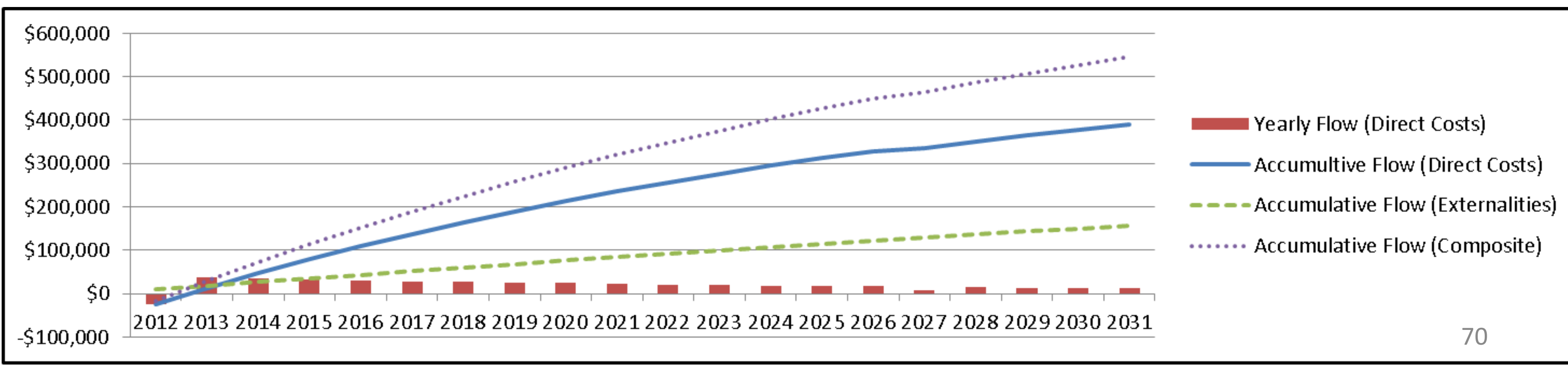
Install Heat Pipe			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$5,056,244	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$5,056,244	$2,004,609
	20 Year Retrofit Costs	Energy Costs	$4,996,605	
		Capital Costs	$40,000	
		O&M Costs	$0	
		Total	$5,036,605	$1,980,712
	Net Present Value (NPV)		**$19,639**	**$23,897**
	Composite NPV		**$43,536**	



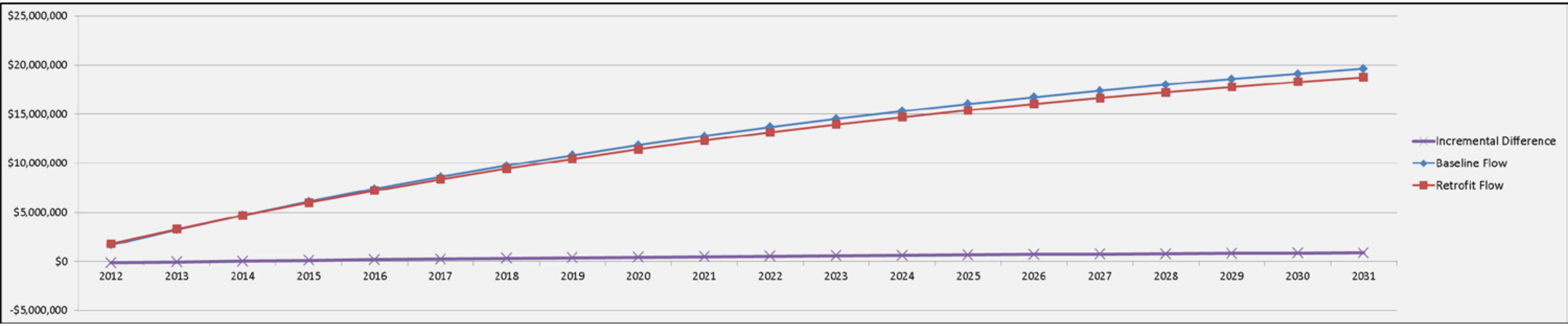
Measure 20: Repair Glycol Run-Around Loop - Fallon



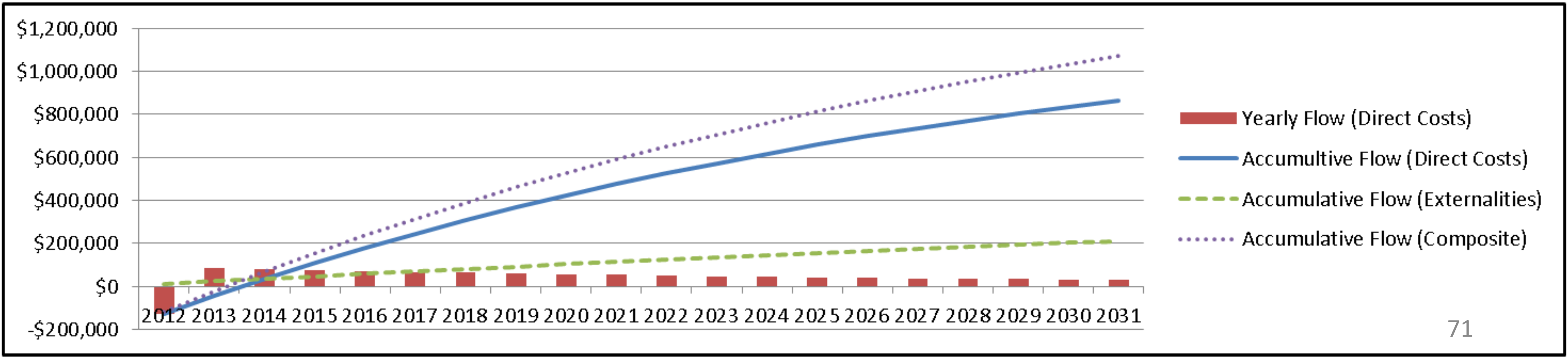
Repair Glycol Run-Around Loop			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$24,742,686	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$24,742,686	$10,607,188
	20 Year Retrofit Costs	Energy Costs	$24,316,300	
		Capital Costs	$32,112	
		O&M Costs	$5,685	
		Total	$24,354,098	$10,450,716
	Net Present Value (NPV)		$388,589	$156,472
	Composite NPV		$545,060	



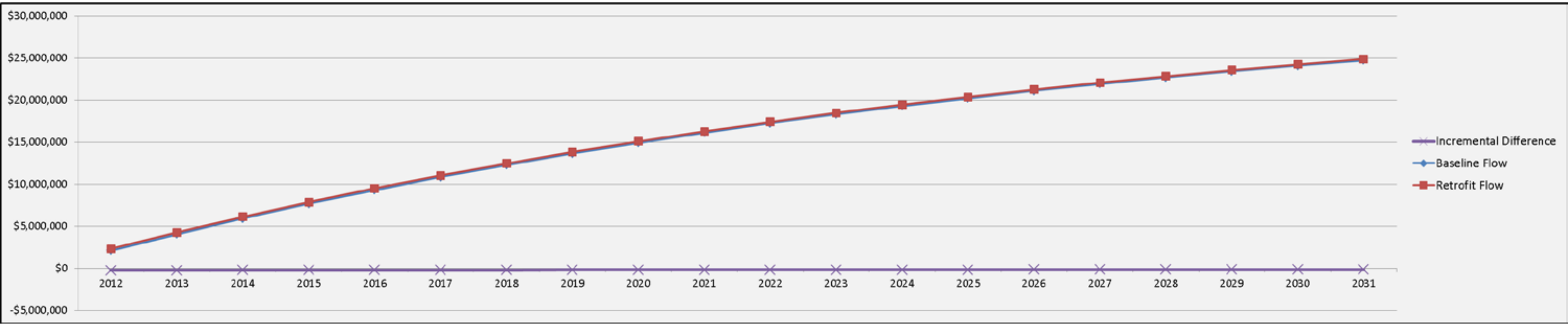
Measure 21: Enable Water-Side Economizer - Fallon



Enable water-side economizer			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$19,621,508	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$19,621,508	$10,607,188
	20 Year Retrofit Costs	Energy Costs	$18,444,456	
		Capital Costs	$131,040	
		O&M Costs	$183,991	
		Total	$18,759,487	$10,396,872
	Net Present Value (NPV)		**$862,021**	**$210,316**
	Composite NPV		**$1,072,337**	



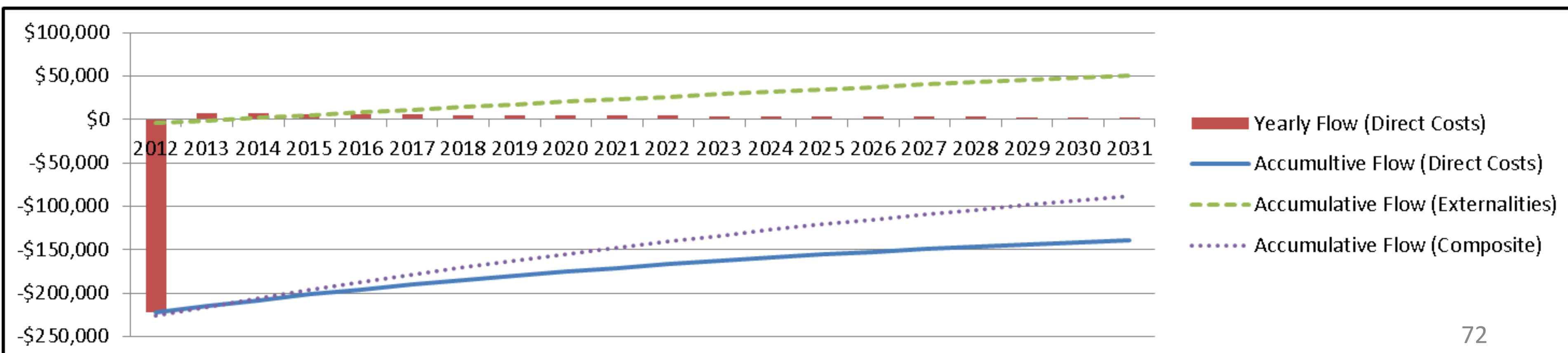
Measure 22: Deep Energy Retrofit, PV - Fallon



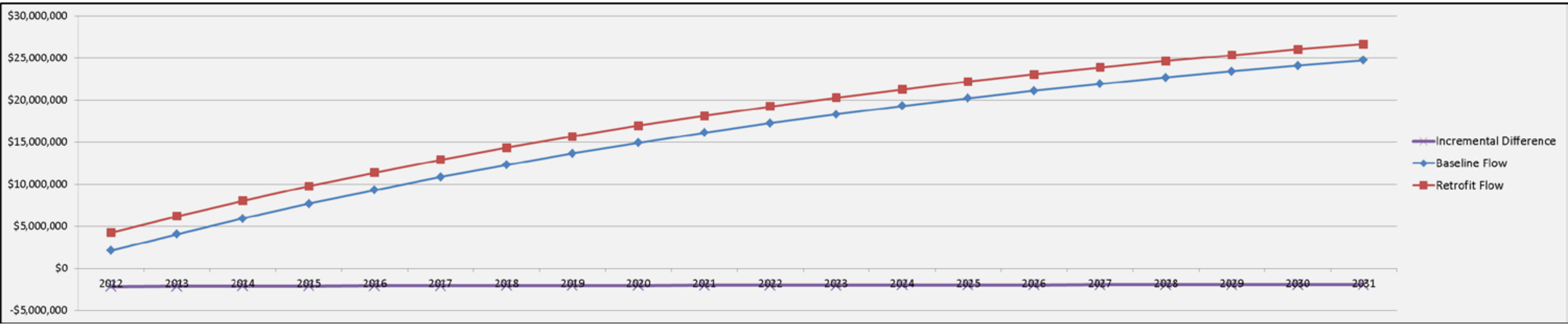
DER - Photovoltaic

		Direct Costs	External Costs
20 Year Baseline Costs	Energy Costs	$24,742,686	
	Capital Costs	$0	
	O&M Costs	$0	
	Total	$24,742,686	$0
20 Year Retrofit Costs	Energy Costs	$24,654,255	
	Capital Costs	$222,000	
	O&M Costs	$5,630	
	Total	$24,881,886	($50,447)
Net Present Value (NPV)		**($139,199)**	**$50,447**
Composite NPV		**($88,752)**	

	Direct Costs	External Costs	Composite Costs
A. Deep Savings Budget ($ in NPV)	$12,567,038	$7,243,448	$19,810,486
B. Measure NPV ($)	($139,199)	$50,447	($88,752)
C. Measure Installed Cost (2012 $ at Year 0)	$613,324	$4,579	$617,903
D. Remaining Budget (A - C)	$11,953,714	$7,238,869	$19,192,583
E. Percent of Budget (C/A)	4.9%	0.06%	3.1%

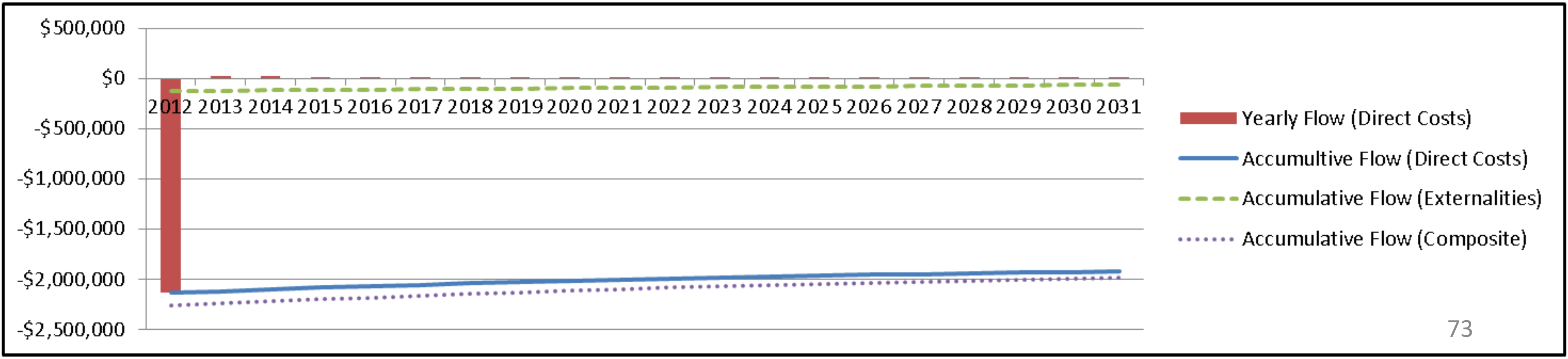


Measure 23: Deep Energy Retrofit, Windows - Fallon

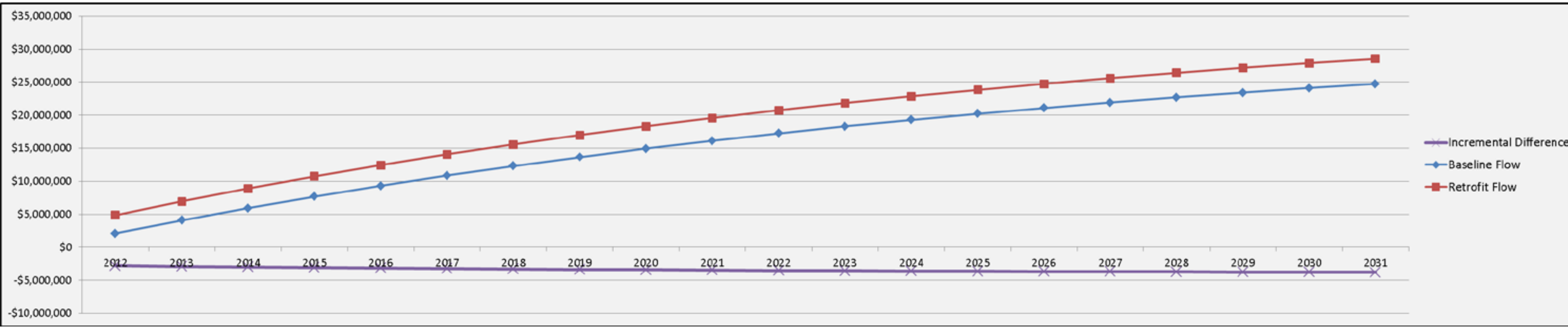


DER - Window Replacement			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$24,742,686	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$24,742,686	$9,270,675
	20 Year Retrofit Costs	Energy Costs	$24,524,709	
		Capital Costs	$2,140,128	
		O&M Costs	$0	
		Total	$26,664,836	$9,334,677
	Net Present Value (NPV)		($1,922,150)	($64,002)
	Composite NPV		($1,986,152)	

	Direct Costs	External Costs	Composite Costs
A. Deep Savings Budget ($ in NPV)	$12,567,038	$7,243,448	$19,810,486
B. Measure NPV ($)	($1,901,882)	($64,002)	($1,965,884)
C. Measure Installed Cost (2012 $ at Year 0)	$2,140,128	$127,115	$2,267,242
D. Remaining Budget (A - C)	$10,426,910	$7,116,333	$17,543,244
E. Percent of Budget (C/A)	17.03%	1.75%	11.4%

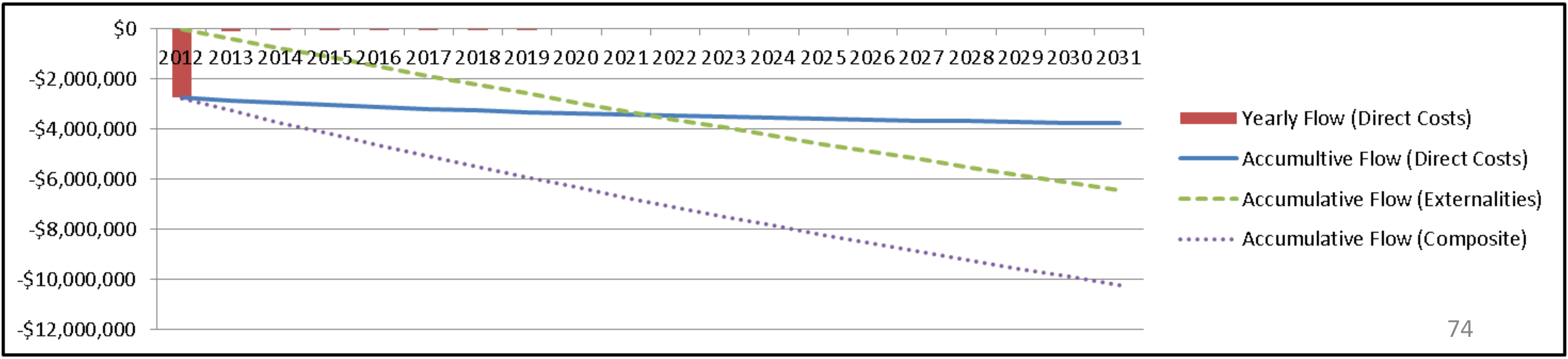


Measure 24: Deep Energy Retrofit, GSHP – Fallon (1 of 3)

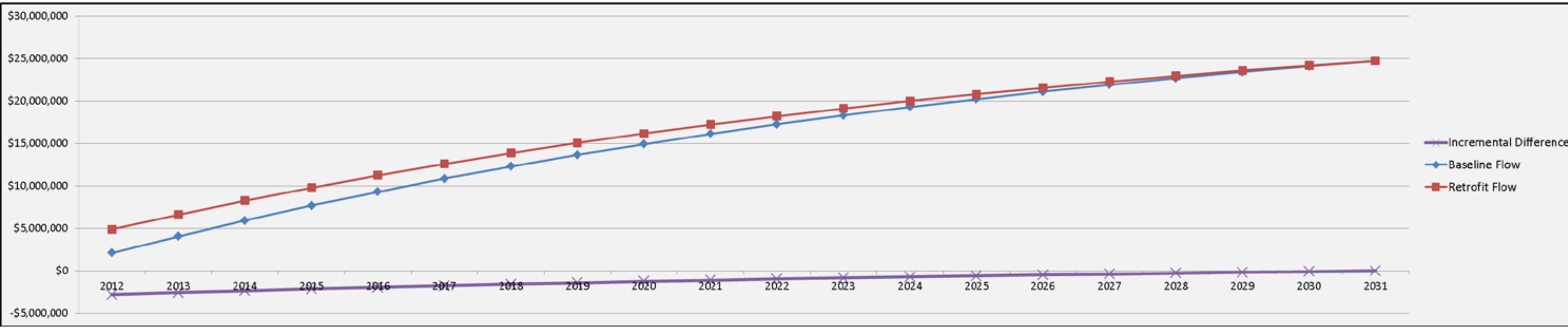


Scenario 1:
Zero Energy Savings

DER - Ground Source Heat Pump			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$24,742,686	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$24,742,686	$9,267,606
	20 Year Retrofit Costs	Energy Costs	$24,742,686	
		Capital Costs	$2,777,832	
		O&M Costs	$1,010,563	
		Total	$28,531,082	$15,718,472
	Net Present Value (NPV)		($3,788,395)	($6,450,866)
	Composite NPV		($10,239,262)	

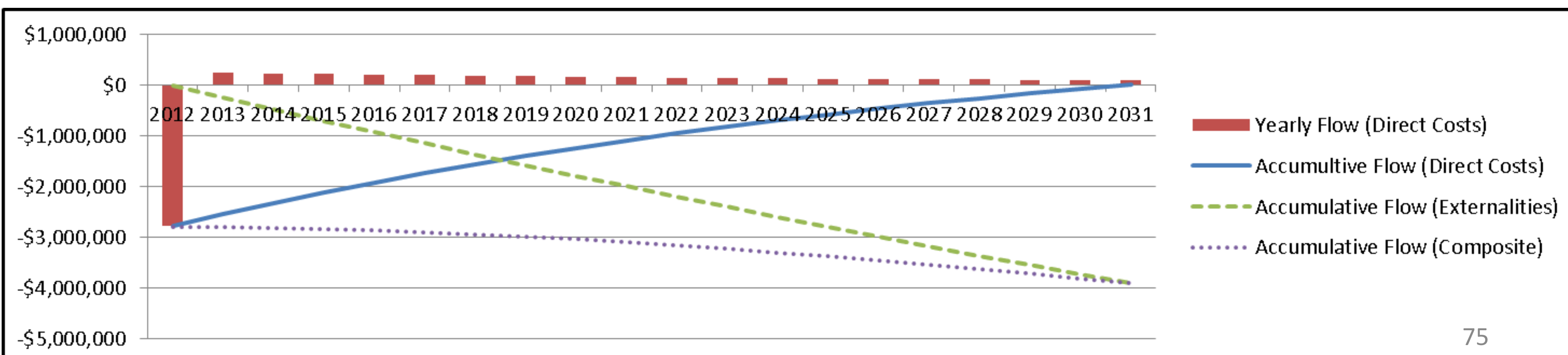


Measure 24: Deep Energy Retrofit, GSHP – Fallon (2 of 3)

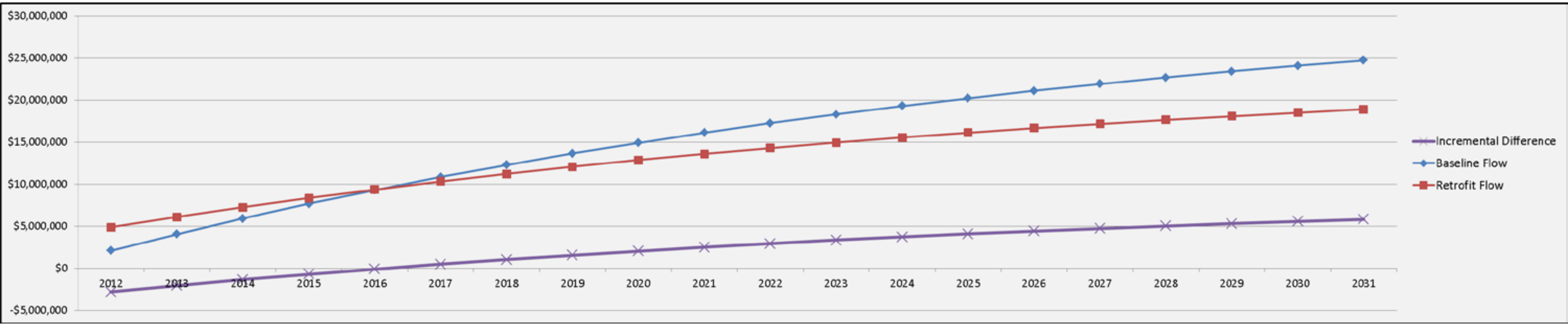


Scenario 2:
Neutral Direct Cost NPV

DER - Ground Source Heat Pump			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$24,742,686	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$24,742,686	$9,267,606
	20 Year Retrofit Costs	Energy Costs	$20,954,250	
		Capital Costs	$2,777,832	
		O&M Costs	$1,010,563	
		Total	$24,742,646	$13,180,633
	Net Present Value (NPV)		**$40**	**($3,913,027)**
	Composite NPV		**($3,912,987)**	



Measure 24: Deep Energy Retrofit, GSHP – Fallon (3 of 3)



DER - Ground Source Heat Pump			Direct Costs	External Costs
	20 Year Baseline Costs	Energy Costs	$24,742,686	
		Capital Costs	$0	
		O&M Costs	$0	
		Total	$24,742,686	$9,267,606
	20 Year Retrofit Costs	Energy Costs	$15,112,905	
		Capital Costs	$2,777,832	
		O&M Costs	$1,010,563	
		Total	$18,901,301	$9,267,568
	Net Present Value (NPV)		**$5,841,385**	**$37**
	Composite NPV		**$5,841,423**	

	Direct Costs	External Costs	Composite Costs
A. Deep Savings Budget ($ in NPV)	$12,567,038	$7,243,448	$19,810,486
B. Measure NPV ($)	$5,841,385	$37	$5,841,423
C. Measure Installed Cost (2012 $ at Year 0)	$2,777,832	$21,792	$2,799,624
D. Remaining Budget (A - C)	$9,789,206	$7,221,656	$17,010,862
E. Percent of Budget (C/A)	22.1%	0.3%	14.1%