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Innovation for Our Energy Future

Renewable Energy Optimization for Land Ports of Entry

Prepared for GSA Public Buildings Service

A. Walker PhD PE, Principal Investigator

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GSA Public Building Service

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0. Executive Summary

The U.S. General Services Administration (GSA) and the Department of Energy's National Renewable Energy Laboratory collaborated to determine the optimal implementation of renewable energy technologies at the 119 GSA-managed Land Ports of Entries. The Renewable Energy Optimization Study evaluated various factors, including start up costs and system performances, to examine the renewable energy resources and applicable renewable energy technologies that could be cost-effectively utilized at the Land Ports of Entries along the country's northern and southern borders.

Renewable energy projects can help GSA meet executive and legislative mandates, including the *Energy Policy Act of 2005* and *Executive Order 13514*, by achieving the following:

1. Provide acceptable return on investment,
2. Increase renewable energy use as percentage of total energy use,
3. Reduce greenhouse gas emissions, especially CO_2 emissions.

The analysis minimizes life cycle costs by finding for each land port of entry site the optimal mix of seven renewable energy technologies: daylighting, wind energy, biomass energy, solar ventilation air preheating, solar water heating, solar electric photovoltaics, and solar industrial process heat technology.

Highlights of the aggregated results include:

- At 109 of the 119 land port of entry sites managed by GSA, optimized mixes of 7 renewable energy technologies can be cost-effective without financial incentives. Based on a 25-year life-cycle analysis, the overall return on investment for these renewable energy solutions is 11.8 percent.

- Implementing all 109 cost effective renewable energy solutions can provide more than 15% of the total energy used at the 119 land port of entry sites in the study. In terms of individual land port of entry sites, renewable energy solutions can provide at least 30 percent of on-site power requirements for 28 of them.

- Implementing all of the cost-effective renewable energy solutions identified will reduce CO_2 emissions by more than 24.38 million pounds each year. That is the equivalent of removing more than 2,100 passenger cars from the road.

The analysis also provides guidance on a regional basis by aggregating total costs for recommended technologies, return on investment, potential percentage

of energy use provided by renewable energy solutions, and CO_2 emissions avoided.

Table ES-0-1: Summary of Renewable Energy Solutions for Land Port of Entry Sites – Costs and Benefits (with and without incentives)

	Without Incentives	With Incentives
Sites with Cost-Effective Renewable Eneregy Solutions	109	115
Initial Cost for Renewable Energy Projects ($)	$17,708,833	$24,799,307
Annual Cost Savings ($/yr)	$1,993,263	$2,659,694
Simple Payback Period (yrs)	8.9	9.3
Return on Investment	11.8%	10.2%
Annual Electric Savings (kWh/yr)	18,734,777	22,904,541
Annual Gas/Fuel Savings (therms/yr)	287,699	515,661
Annual CO_2 Emissions Avoided (million lb/yr)	24.38	31.54
Renewable Energy Use as Percentage of Total Energy Use	15%	22%

No matter what criteria is applied, this analysis shows that implementing renewable energy technologies can help GSA meet its operational energy goals at land port of entry sites cost effectively.

1. Introduction

The U. S. General Services Administration (GSA) is a leader among federal agencies in aggressively pursuing energy efficiency opportunities for its facilities and installing in its facilities renewable energy (RE) systems for heat and power. As the largest building owner in the country, GSA has a substantial opportunity to offset building energy loads through RE projects. Not only is GSA committed to incorporating principles of sustainable design and energy efficiency into its building projects, but GSA's client agencies also look to GSA for strategies to meet performance requirements set by various federal mandates.

Federal Mandates

Executive and legislative mandates over the last few years have raised the performance requirements for buildings in GSA's national real estate portfolio and established RE and sustainability guidelines for all federal agencies.

The *Energy Policy Act of 2005* (*EPAct 2005)* directs federal agencies to implement RE projects to reach specific goals:

- Federal agencies must have 7.5 percent or more of their electricity consumption be RE by fiscal year (FY) 2013.
- Federal agencies receive double credit toward the 7.5 percent goal for RE produced on-site or from RE produced on federal land and used at a federal facility.

In January 2006, President Bush's *Memorandum of Understanding for Federal Leadership in High Performance and Sustainable Buildings* committed "federal leadership in the design, construction, and operation of High-Performance and Sustainable Buildings." It charged agencies with implementing building design and operation strategies that provide optimal performance and maximize lifecycle asset value.

In October 2009, President Obama established a government-wide focus on sustainability, energy efficiency, and the environment with *Executive Order* (*EO) 13514*. Federal agencies must meet a series of goals, including the following:

- Set a percentage reduction target for agency-wide reductions of scope 1 and 2 greenhouse gas (GHG) emissions in absolute terms by FY 2020, relative to a FY 2008 baseline.
- Submit a comprehensive GHG inventory.

Land Ports of Entry (LPOEs) and RE Resources

RE resources can not only help agencies reduce metered energy use, but they can also help agencies reduce their GHG emissions. At the more than 100 LPOEs that GSA manages along the northern and southern borders, the benefits and opportunities go even further.

Many LPOEs are located away from population centers and must pay higher utility prices to cover the cost of long-distance transmission. RE solutions not only have the potential to reduce carbon emissions and lower energy costs for LPOEs, but they also have the potential to support continuity of operations (COOP) for the sites. Reliable RE solutions have the potential to replace the backup generators and fuel storage that every LPOE has in place.

Renewable Energy Optimization (REO) Study

In order to find the most appropriate RE solutions for each LPOE site, GSA engaged the National Renewable Energy Laboratory (NREL) to perform this Renewable Energy Optimization (REO) Study. The scope of this study is to evaluate 119 LPOE sites to identify RE resources and technologies that will cost effectively reduce metered electrical and thermal energy consumption.

2. Study Objectives

In order to determine the optimal implementation of RE technologies at the 119 GSA-managed LPOE sites, the REO Study evaluated various factors, including start up costs and system performances. The study objectives are to determine which LPOE sites could have RE projects that

1. Provide acceptable return on investment (ROI),
2. Increase RE energy use as percentage of total energy use,
3. Reduce GHG emissions, especially CO_2 emissions.

The challenge in determining the optimal combination of RE technologies for each LPOE site stems from multiple sources:

- Different LPOE sites have different operating parameters and costs;
- Different LPOE sites have different RE resources available;
- The effectiveness of RE resources varies from site to site;
- Different LPOE sites have different energy costs;
- Different LPOE sites qualify for different financial incentives, including tax and utility-based incentives.

As a result, the same system installed at different sites may generate different amounts of electricity, have significantly different payback periods, and result in different amounts of CO_2 emissions avoided.

The recommendations from this REO Study are meant to help simplify the decision making process for GSA energy managers in selecting RE projects to implement. It adheres to the following guidelines:

- This study provides vendor-neutral recommendations in terms of technologies.
- The analysis aims to minimize life cycle costs.

It is worth noting that if a technology is recommended as part of the optimized solution for a site, the solution includes the size that minimizes life-cycle costs. In other words, it is possible for an LPOE site to cost effectively generate more RE than the optimized solution indicates, but the life cycle costs would be higher.

3. Methodology

3.1. *Iterative "Solving"*

The REO Study found the optimal combination and size of renewable energy solutions at each LPOE site by running iterative "what if" scenarios. Each optimal solution provides the maximum energy achievable at the minimum life-cycle cost. The optimization routine used the following list of collected, calculated, and iteratively optimized data:

- Current energy use of each LPOE site,
- Available RE resources at each site,
- Land use requirements, which can constrain solar and wind energy applications,
- Life-cycle costs of the base case for each site,
- Life-cycle costs of the RE solutions case for each site.

The NREL REO tool takes into account the effect of all RE systems being optimized for a site and adjusts the systems sizing accordingly. For example, adding a significant amount of daylighting to a building would not only reduce the lighting load, but it would also reduce the overall building electric load and alter the heating and cooling requirements. The REO tool accounts for these changes when sizing all of the systems.

Based on the optimal combination and size of RE solutions, the Study calculated energy savings and CO_2 emissions avoided for each LPOE site.

The analysis then compares the base case to the optimal RE solutions both with and without financial incentives. The basis for the results and recommendations in Section 4 include the following factors:

- ROI,
- RE use as percentage of total energy use,
- CO_2 emissions avoided.

See Appendix A Section A.4 for more details on the optimization routine. See Appendix B for the detailed results of life-cycle cost optimization without financial incentives. See Appendix C for the detail results of life-cycle cost optimization with financial incentives.

3.2. *Site Factors*

The Study used site information from multiple sources. For each LPOE facility, GSA provided the following data:

- Site address,
- Site latitude/longitude,
- Total facility square footage, and when available, building loads, building sizes, building primary use,
- FY 2007-2008 annual utility energy use and cost, including gas, electric, oil, propane, and steam.

NREL provided site-specific resource and incentive information from its RE resource databases [ref. 1]. Platts, Inc. databases detailed local energy costs and wholesale power costs.

The Study used DOE's multipliers for CO_2 emissions per kWh of electricity use for each location, and it used a standard multiplier for CO_2 emissions per therm of natural gas consumption for all locations.

The Study estimates the installed cost, including incentive timeframe and tax depreciation, by using the Database of State Incentives for Renewables & Efficiency (DSIRE) database maintained by the University of North Carolina.

GSA cannot directly utilize the tax incentives included in this analysis, but it can benefit indirectly from pass-through cost savings. Therefore, the Study assumes a typical corporate tax liability structure in the 35 percent tax bracket for estimating the effects of business investment tax credit and accelerated depreciation.

3.3. *Economic Factors*

In the life-cycle cost analysis, NREL used a discount rate of 4.6 percent to represent the time-value of money, consistent with rates published by the National Institute of Standards and Technology (NIST) for federal analysis [ref. 2]. It used the same publication, *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis*, for other parameters used in the economic analysis, such as fuel escalation rate and general inflation rate.

Initial cost, efficiency, and operation and maintenance cost for each of the renewable energy technologies is characterized according to the cost and performance data reported in edition four of the *Power Technologies Energy Data Book* [ref. 8] and also from *Renewable Energy Technology Characterizations* [ref. 10]. Other sources were incorporated to establish the

economic parameters for costing. The *RS Means Green Building: Project Planning and Cost Estimating* [ref. 7] was used for installed cost estimates with regional adjustment factors applied. Energy performance and cost savings were based on experience with the technologies gained in other NREL analyses.

3.4. ***Renewable Energy Technologies***

This study examined RE technologies with the highest potential for LPOE sites. These technologies have been tested, refined, optimized, and deployed in recent decades. This section provides brief descriptions of the RE technologies. For technical details on the RE technologies, please refer to Appendix A Section A.2 of this report. A summary of the analysis results are in Section 4.

- Daylighting reduces the need for artificial light. Complete daylighting systems include apertures (skylights, light shelves, and windows) to admit and distribute sunlight and a controller to modulate artificial light as needed to maintain the desired level of light for the building space.

- Wind Energy can generate electricity cost effectively in many regions. Due to load and land constraints, the Study only considers one or two turbines for each LPOE site. The installed costs are therefore significantly higher than the wind farm industry norms.

- Biomass Energy is fuel, heat, or electricity produced from organic materials, such as plants, agricultural residues, forestry by-products, and municipal or industrial wastes. This analysis considered 10 configurations of systems for LPOE sites using biomass, such as wood mill waste from surrounding areas.

- Solar Resources

    - Solar Ventilation Air Preheating (SVP) systems use the sun's heat to warm air before it is brought into the building's heating, ventilation, and air conditioning (HVAC) system. Adding inexpensive hot air generated on cold sunny days to the supply air of an HVAC system can lower heating bills.

    - Solar Water Heating systems use the sun to heat water that is stored in tanks for later use. The conventional hot water heating system is used as a back-up to the solar system. Buildings at LPOE sites that use expensive electricity or propane to heat water will benefit from adding solar water heating systems when expanding or remodeling.

    - Solar Electric Photovoltaics (PV) modules convert sunlight directly into electricity with no moving parts, no noise, no pollution, and very little

maintenance. Over the past two decades, there have been significant improvements in the efficiency of PV materials and the manufacturing costs, yet PV is still more expensive than conventional grid electricity in the U.S. PV's cost effectiveness is dependent to a large degree on the local, state, or utility incentive programs coupled with tax-based incentives.

- Solar Industrial Process Heat Technology systems achieve higher temperatures at a faster speed than do other solar heat collectors. This intensity and speed make solar industrial process heat systems more suitable for various industrial applications. The application modeled in this study is hot water heating.

4. Analysis Results: RE Solutions for LPOE Sites

The REO Study analyzed cost-effectiveness both with and without financial incentives. While GSA cannot utilize the tax credits directly, it can benefit indirectly. For example, a third party could utilize the tax credits and pass on some of the savings to GSA in an alternative financing mechanism such as an Energy Savings Performance Contract (ESPC).

The analysis results are presented in tables intended to help decision makers prioritize the implementation of RE solutions at GSA-managed LPOE sites.

- Section 4.1 aggregates the results from a portfolio-wide perspective.
- Section 4.2 discusses the results by GSA regions and show how benefits are distributed across regions.
- Section 4.3 highlights LPOE sites with the highest potential for RE solutions.

Note: Results from this study are for screening purposes only. Prior to any project implementation, GSA must conduct a detailed technical engineering and economic feasibility study.

4.1. *Portfolio Findings*

RE can be cost effective for over 90 percent of the LPOE sites in GSA's portfolio with or without financial incentives. Implementing all of the optimized RE solutions can provide more than 15 percent of the total energy consumed by all 119 LPOEs in the study and reduce CO_2 emissions by more than 24.4 million pounds each year. That is equivalent to taking more than 2,100 passenger cars off the road each year.

When financial incentives are considered, projects at 6 sites become feasible, bringing the total number of cost-effective solutions to 115. As Table 4-1 shows, this increases RE use as percent of total energy use, total energy savings, and CO_2 emissions avoided. At the same time, this increases the total initial cost for RE projects and the simple payback period, and it lowers the ROI.

Table 4-1: Summary of Solutions for LPOE Sites – Costs and Benefits (with and without incentives)

	Without Incentives	With Incentives
Sites with Cost-Effective RE Solutions	109	115
Initial Cost for RE Projects ($)	$17,708,833	$24,799,307
Annual Cost Savings ($/yr)	$1,993,263	$2,659,694
Simple Payback Period (yrs)	8.9	9.3
ROI	11.8%	10.2%
Annual Electric Savings (kWh/yr)	18,734,777	22,904,541
Annual Gas/Fuel Savings (therms/yr)	287,699	515,661
Annual CO_2 Emissions Avoided (million lb/yr)	24.38	31.54
RE Use as Percentage of Total Energy Use	15%	22%

The analysis results are summarized below from a technology perspective. Appendix B includes tables that show the detailed calculations for each technology. This summary and those individual technology tables do not represent the optimal case for the technology when considered in isolation. Instead, they represent the calculations that support each technology as a part of the optimal solution that includes all 7 technologies considered in this study.

Cost-effectiveness is defined here as having a simple payback period of less than 17 years.

- **Daylighting** is cost effective at 103 LPOE sites as part of the RE Solution Case. Payback periods ranged from under 4 years to the less than 17 years. Cost-effective sites were primarily on the southern border where there is not excessive heat loss through skylights in the winter. Note that the cost estimates used for the study are for industry standard skylights and do not include costs for the security enhancements specified in the LPOE Design Guide.

- **Wind energy** is cost effective at 11 LPOE sites using wind resource data from nearby recording stations. However, it is difficult to assess wind technology without on-site resource data. Therefore, it is important to conduct on-site measurements prior to implementing any wind energy project. Use of wind energy is also constrained by available land area.

- **Biomass gasification** is cost effective at 10 LPOE sites where biomass resources are plentiful and conventional fuel costs are high. **Anaerobic digestion for biomass energy** is not cost effective at any LPOE site.

- **Solar ventilation air preheating** (SVP) is cost effective at 76 northern LPOE sites that use heat for much of the year.

- **Solar water heating** is cost effective at 55 LPOE sites. The results depend heavily on the availability of solar resource and the utility rates.

- **Solar electric photovoltaic** (PV) arrays are only cost effective with sufficient local incentive programs. With incentives, PV installations are cost effective at 3 sites.

- **Solar industrial process heat** is not cost effective at any of the LPOE sites, even with incentive programs. The limited demand for hot water at LPOEs does not warrant the significant investment required to implement this technology.

4.2. *GSA Regional Findings*

This section discusses the analysis results for the seven GSA regions that have LPOEs. Regions 3, 4, and 6 are not part of this study because they do not have any LPOEs

Table 4-2 offers an overview of the three main factors used in the analyses.

- ROI is highest in Regions 7 and 9.
- RE use as percentage of total energy use is highest in Regions 1, 2, 7, and 9.
- CO_2 emissions avoided are not only highest in Regions 7 and 9, but they are significantly higher in those regions than in the other regions.

Regions 7 and 9 stand out from the group because they have the highest potential for cost savings and environmental benefits. At the same time, every GSA region can leverage the optimal solutions to meet the scope 2 GHG emissions reduction goals GSA must set under *EO 13514*.

Table 4-2: Summary of Analysis Results by GSA Region (without incentives)

	GSA Region							
	1	2	5	7	8	9	10	Overall
ROI	10.4%	10.4%	8.2%	13.9%	10.0%	15.0%	11.6%	**11.8%**
RE Use as Percent of Total Energy Use	18.60%	17.60%	10.60%	19.90%	11.20%	17.60%	12.40%	**16.80%**
Total CO_2 Emissions Avoided (million lb/yr)	1.11	2.24	0.41	10.17	0.88	7.68	1.89	**24.38**

4.3. *LPOE Site-Specific Findings*

Overall, this analysis identified 28 LPOE sites where on-site RE solutions could cost-effectively generate, without incentives, at least 30 percent of the current power requirements for those individual sites (Table B-2).

Tables 4-3, 4-4, and 4-5 highlight the LPOE sites with the highest potential based on each of the three main factors used in the analysis. Three LPOEs show up in more than one of these tables:

- **Calexico, CA** is in both the highest ROI & highest CO_2 emissions avoided tables.
- **Niagra Falls, NY** and **Columbia, TX** are in both the highest CO_2 emissions avoided & the RE is highest percentage of total energy use tables.

Table 4-3: Sites with Highest ROI (without incentives)

LPOE Site Name	RE Solution Initial Cost	RE Case Life-Cycle Cost	Base Case Life-Cycle Cost	RE Solution Case Return on investment
Oroville, WA	$10,415	$1,201,469	$1,254,894	44.80%
Fabens, TX	$46,957	$640,297	$777,609	27.40%
Sasabe, AZ	$32,691	$377,290	$456,025	23.30%
Columbus, NM	$95,087	$799,531	$976,752	19.90%
Tecate, CA	$224,279	$1,963,062	$2,367,343	19.70%
Santa Teresa, NM	$88,330	$2,422,683	$2,593,983	19.40%
Donna TX (not built yet)	$14,708	$280,294	$307,574	18.90%
Paso Del Norte, TX	$117,746	$2,496,897	$2,712,162	18.70%
Baudette, MN	$16,701	$120,794	$147,275	18.50%
Calexico, CA	$627,943	$6,069,151	$7,063,869	18.00%
Ysleta, TX	$259,146	$3,642,882	$4,089,669	18.00%

Ten LPOE sites did not have cost-effective applications of RE technologies:

- San Luis AZ (not yet built at the time of analysis);
- Amb. Bridge, MI;
- Intl Bridge, MI;
- Rooseville, MT;
- Admin, TX (leased);
- El Paso, TX (out leased);
- McAllen TX (not yet built at the time of analysis);
- Highgate Springs 1, VT;
- Mataline Falls. WA;
- Sumas, WA.

The costs for each RE technology making up the best mix at each LPOE site are detailed in Table B-6. High initial cost indicates more applicable RE solutions for a site.

Table 4-4: Sites where RE is Highest Percentage of Total Energy Use (without incentives)

LPOE Site Name	Base Case Energy Use (Mbtu/yr)	RE Solution Case Energy Use (Mbtu/yr)	RE Energy Use as Percentage of Total Energy Use
Turner, MT	53	-21	140.8%
Niagra Falls, NY	6,647	2,093	68.5%
Laurier, WA	243	98	59.8%
Marfa, TX	2,098	845	59.7%
Coburn Gore, ME	1,531	620	59.5%
Sweetgrass, MT	2,488	1,081	56.6%
Fort Kent, ME	1,609	712	55.7%
Alburg, VT (Joint ownership)	142	71	50.2%
Orient, ME	159	83	47.6%
Columbia, TX	7,275	3,811	47.6%
TOTAL FOR ALL SITES	**496,508 Mbtu/yr**	**420,694 Mbtu/yr**	**15.3%**

Table 4-5: Sites with Highest Amounts of CO_2 Emissions Avoided (without incentives)

LPOE Site Name	Total CO_2 Avoided (lbs/yr)
Calexico, CA	2,546,211
Columbia, TX	1,875,724
Los Tomates, TX	1,497,101
Niagra Falls, NY	1,236,660
San Luis, AZ	1,222,237
Kika de la Garza, TX	1,122,215
Gateway, TX	987,248
San Ysidro, CA	835,994
DOT, TX (leased)	742,297
Otay Mesa, CA	683,254

Table 4-6 shows the RE solutions for each site. More detailed calculations and results are in Appendix B and Appendix C.

Table 4-6: RE Solutions that Minimize Life Cycle Cost (without incentives)

	Wind Capacity (kW)	Solar Vent Preheat Area (ft^2)	Solar Water Heating Area (ft^2)	Biomass Gasifier Size (M Btu/h)	Biomass Gasifier Cogen Size (kW)	Daylighting non-Office Skylight/Floor Area Ratio	Daylighting Office Skylight/Floor Area Ratio	Total CO_2 prevented (lbs/yr)	Total Initial Cost ($)	Return on investment (%)
Calexico, CA	0	0	3,062	0.25	24	4.60%	2.90%	2,546,211	$563,968	18.00%
Columbia, TX	0	0	2,104	0.21	23	5.20%	4.40%	1,875,724	$1,102,447	14.10%
Los Tomates, TX	307	0	0	0	0	5.70%	4.00%	1,497,101	$1,131,309	9.50%
Niagra Falls, NY	148	8,444	2,592	0.13	13	3.80%	4.50%	1,236,660	$1,520,782	9.60%
San Luis, AZ	0	0	1,445	0.17	17	4.70%	3.80%	1,222,237	$283,260	11.20%
Kika de la Garza, TX	272	0	0	0	0	5.50%	4.00%	1,122,215	$1,054,667	7.40%
Gateway, TX	209	0	0	0	0	5.60%	4.00%	987,248	$811,736	9.10%
San Ysidro, CA	790	0	0	0	0	4.50%	3.80%	835,994	$1,039,517	12.40%
DOT, TX (leased)	0	661	1,266	0	0	4.50%	3.00%	742,297	$214,277	11.20%
Otay Mesa, CA	467	0	0	0	0	4.70%	3.90%	683,254	$1,215,074	12.70%
Juarez-Lincoln, TX	0	0	0	0	0	5.40%	3.30%	660,576	$1,570,100	15.60%
Ysleta, TX	0	0	0	0	0	5.80%	3.40%	556,311	$259,146	18.00%
Brownsville/Matamoros TX	102	0	0	0	0	5.50%	4.50%	517,768	$466,410	7.70%
Tecate, CA	0	0	1,028	0.12	12	4.60%	4.10%	497,800	$251,264	19.70%
Bridge of the Americas, TX	0	0	0	0	0	5.60%	3.20%	471,392	$956,498	17.80%
Sweetgrass, MT	0	1,261	547	0.11	12	4.50%	4.50%	467,707	$287,272	13.00%

Table 4-6: RE Solutions that Minimize Life Cycle Cost (without incentives)

	Wind Capacity (kW)	Solar Vent Preheat Area (ft^2)	Solar Water Heating Area (ft^2)	Biomass Gasifier Size (M Btu/h)	Biomass Gasifier Cogen Size (kW)	Daylighting non-Office Skylight/Floor Area Ratio	Daylighting Office Skylight/Floor Area Ratio	Total CO_2 prevented (lbs/yr)	Total Initial Cost ($)	Return on investment (%)
Lukeville, AZ	0	2,380	592	0	0	4.60%	4.20%	447,579	$83,007	15.70%
Blaine, WA	0	3,316	256	0	0	4.90%	4.20%	395,219	$178,267	8.30%
Del Rio, TX	0	0	2,082	0	0	5.50%	3.60%	354,066	$269,257	11.00%
Progreso, TX	0	0	627	0	0	4.50%	3.60%	352,624	$70,912	10.20%
Columbus, NM	0	880	436	0	0	4.90%	4.50%	348,861	$105,673	19.90%
Marfa, TX	36	2,292	337	0	0	4.30%	4.00%	342,501	$238,443	6.90%
Point Robert, WA	0	3,248	223	0	0	4.40%	4.10%	340,688	$156,023	7.90%
Los Indios, TX	0	0	0	0	0	5.50%	3.90%	337,904	$163,432	15.10%
Alexandria Bay, NY	131	3,640	0	0	0	4.70%	3.60%	300,300	$600,386	7.70%
Blaine, WA	0	3,316	0	0	0	0.00%	0.00%	287,270	$162,654	7.90%
Andrade, CA	27	97	275	0	0	4.60%	4.40%	286,670	$166,715	9.20%
Calexico West, CA	0	0	0	0	0	4.50%	3.70%	284,124	$162,695	17.70%
Eagle Pass, TX	0	0	0	0	0	5.30%	3.90%	268,144	$127,361	15.60%
Champlain, NY	0	6,739	0	0	0	5.40%	3.20%	267,704	$805,137	9.10%
Ogdensburg NY	0	5,614	0	0	0	6.20%	4.50%	247,756	$401,922	12.30%
Paso Del Norte, TX	0	0	0	0	0	5.60%	3.40%	243,506	$117,746	18.70%
Alcan, AK	0	4,220	3,452	0	0	0.00%	0.00%	231,312	$368,140	11.10%

Table 4-6: RE Solutions that Minimize Life Cycle Cost (without incentives)

	Wind Capacity (kW)	Solar Vent Preheat Area (ft^2)	Solar Water Heating Area (ft^2)	Biomass Gasifier Size (M Btu/h)	Biomass Gasifier Cogen Size (kW)	Daylighting non-Office Skylight/Floor Area Ratio	Daylighting Office Skylight/Floor Area Ratio	Total CO_2 prevented (lbs/yr)	Total Initial Cost ($)	Return on investment (%)
Nogales, AZ	0	0	0	0	0	4.50%	3.50%	226,444	$272,040	16.50%
Douglas, AZ	0	1,623	1,158	0	0	4.50%	3.60%	221,282	$216,247	9.40%
Eastport, ID	0	1,592	0	0	0	0.00%	0.00%	212,449	$60,444	12.30%
Nogales, AZ	0	0	0	0	0	4.50%	3.30%	205,329	$231,210	14.00%
Houlton, ME	0	2,832	0	0.11	11	0.00%	0.00%	199,672	$188,485	10.20%
Santa Teresa, NM	0	0	0	0	0	5.40%	4.20%	192,536	$88,330	19.40%
Fabens, TX	0	376	242	0	0	5.00%	4.40%	179,669	$50,618	27.40%
Coburn Gore, ME	0	269	556	0.1	11	4.60%	4.30%	162,941	$133,128	10.30%
Fort Kent, ME	0	582	0	0.11	12	4.50%	4.20%	159,312	$113,095	12.60%
Sasabe, AZ	0	1,035	184	0	0	4.50%	4.30%	150,700	$27,395	23.30%
Blaine, WA	0	0	0	0	0	5.70%	4.40%	147,642	$79,050	7.80%
Detroit Cargo, MI	0	0	0	0	0	4.50%	3.00%	132,099	$77,868	9.10%
Pembina, ND	0	3,831	0	0	0	0.00%	0.00%	127,626	$78,327	11.50%
Piegan, MT	0	1,307	0	0	0	2.70%	3.00%	126,334	$203,861	8.80%
Convent, TX	0	0	0	0	0	4.50%	3.20%	112,696	$62,574	13.10%
Roma, TX	0	0	554	0	0	4.50%	3.30%	99,675	$104,305	11.50%
Rio Grande City, TX	0	0	0	0	0	4.50%	3.20%	95,228	$52,686	14.90%

Table 4-6: RE Solutions that Minimize Life Cycle Cost (without incentives)

	Wind Capacity (kW)	Solar Vent Preheat Area (ft^2)	Solar Water Heating Area (ft^2)	Biomass Gasifier Size (M Btu/h)	Biomass Gasifier Cogen Size (kW)	Daylighting non-Office Skylight/Floor Area Ratio	Daylighting Office Skylight/Floor Area Ratio	Total CO_2 prevented (lbs/yr)	Total Initial Cost ($)	Return on investment (%)
McAllen, TX	0	0	0	0	0	5.20%	4.20%	91,170	$44,664	16.40%
Roseau, MN	0	2,898	0	0	0	0.00%	0.00%	89,728	$60,384	7.40%
Grand Portage, MN	0	1,541	0	0	0	4.50%	3.50%	84,413	$46,132	10.20%
Laredo TX	0	0	0	0	0	5.10%	4.40%	80,858	$40,968	15.10%
Derby Line, VT	0	1,735	216	0	0	4.70%	3.30%	73,736	$68,033	11.10%
Naco, AZ	0	358	387	0	0	4.50%	4.10%	73,221	$51,751	10.00%
Highgate Springs 2, VT	0	2,087	0	0	0	4.40%	2.80%	72,555	$64,603	8.50%
Porthill, ID	0	499	89	0	0	0.00%	0.00%	59,810	$17,636	11.30%
Baudette, MN	0	342	59	0	0	0.00%	0.00%	56,804	$12,971	18.50%
Massena, NY	0	1,627	703	0	0	0.00%	0.00%	54,160	$61,232	9.10%
Raymond, MT	0	1,555	0	0	0	0.00%	0.00%	54,091	$162,206	15.20%
Ferry Point, ME	0	1,577	223	0	0	0.00%	0.00%	49,005	$53,260	11.60%
Laurier, WA	0	406	52	0	0	4.60%	4.20%	47,871	$28,998	13.10%
Dalton Cache, AK	0	1,275	189	0	0	4.20%	4.50%	40,803	$69,718	17.50%
St John Hwy, NY	0	1,171	389	0	0	0.00%	0.00%	35,322	$43,177	9.50%
Danville, WA	0	823	0	0	0	4.70%	4.10%	33,632	$29,056	7.80%
Donna TX (not built)	0	0	0	0	0	4.90%	4.50%	33,332	$14,708	18.90%

Table 4-6: RE Solutions that Minimize Life Cycle Cost (without incentives)

	Wind Capacity (kW)	Solar Vent Preheat Area (ft^2)	Solar Water Heating Area (ft^2)	Biomass Gasifier Size (M Btu/h)	Biomass Gasifier Cogen Size (kW)	Daylighting non-Office Skylight/Floor Area Ratio	Daylighting Office Skylight/Floor Area Ratio	Total CO_2 prevented (lbs/yr)	Total Initial Cost ($)	Return on investment (%)
Skagway, AK	0	813	291	0	0	4.30%	4.40%	33,071	$48,638	13.70%
Fort Hancock, TX	0	160	300	0	0	4.60%	4.40%	31,814	$34,040	14.00%
Vanceboro, ME	0	733	167	0	0	4.50%	4.30%	30,838	$39,361	10.90%
Noyes, MN	0	902	0	0	0	0.00%	0.00%	30,033	$16,334	13.80%
Trout, River, NY	0	730	210	0	0	4.50%	4.00%	28,618	$39,965	9.70%
Rouses Pt. NY	0	651	258	0	0	4.50%	4.00%	27,408	$41,852	8.60%
Madawaska, ME	0	548	136	0	0	4.50%	4.30%	26,566	$40,831	11.10%
Derby Line, VT	0	575	0	0	0	4.50%	3.70%	26,345	$82,862	11.90%
Beecher Falls, VT	0	483	170	0	0	4.50%	3.90%	26,315	$35,071	10.80%
Mataline Falls. WA	0	0	0	0	0	0.00%	0.00%	25,480	$0	-
Jackman, ME	0	916	0	0	0	0.00%	0.00%	25,217	$19,242	11.50%
Portal, ND	0	714	0	0	0	0.00%	0.00%	24,882	$15,519	6.40%
Alburg, VT (Joint ownership)	0	261	34	0	0	4.20%	4.50%	24,841	$18,302	15.00%
Kenneth Ward, WA	0	0	0	0	0	5.10%	4.80%	24,412	$66,931	8.60%
VanBuren, ME	0	778	117	0	0	0.00%	0.00%	24,227	$28,212	10.90%
Richford, VT	0	438	145	0	0	4.50%	4.00%	22,076	$30,561	10.00%
Turner, MT	2	161	10	0	0	4.40%	4.20%	21,589	$33,887	8.00%

Table 4-6: RE Solutions that Minimize Life Cycle Cost (without incentives)

	Wind Capacity (kW)	Solar Vent Preheat Area (ft^2)	Solar Water Heating Area (ft^2)	Biomass Gasifier Size (M Btu/h)	Biomass Gasifier Cogen Size (kW)	Daylighting non-Office Skylight/Floor Area Ratio	Daylighting Office Skylight/Floor Area Ratio	Total CO_2 prevented (lbs/yr)	Total Initial Cost ($)	Return on investment (%)
East Richford, VT	0	471	0	0	0	4.50%	3.90%	19,585	$29,045	11.80%
West Berkshire,VT	0	412	104	0	0	4.50%	4.30%	18,574	$25,660	8.90%
Fort Fairfield, ME	0	377	114	0	0	4.50%	4.40%	18,169	$26,212	11.80%
Norton, VT	0	392	0	0	0	4.50%	5.10%	17,880	$19,900	11.10%
Dunseith, ND	0	528	0	0	0	0.00%	0.00%	17,690	$11,131	9.50%
North Troy VT	0	326	81	0	0	4.50%	3.70%	15,738	$19,854	7.20%
Chief Mt, MT	0	466	0	0	0	0.00%	0.00%	15,677	$12,461	5.10%
St. Francis, ME	0	116	32	0	0	0.00%	0.00%	15,624	$4,196	14.40%
Fort Covington, NY	0	334	165	0	0	4.50%	4.20%	15,178	$24,426	9.30%
St. Francis, ME	0	33	36	0	0	0.00%	0.00%	14,783	$3,542	10.10%
Canaan, VT	0	248	120	0	0	4.50%	4.30%	14,387	$20,990	9.70%
Limestone, ME	0	286	109	0	0	4.50%	4.40%	14,340	$57,152	11.80%
Chateaugay, NY	0	389	203	0	0	0.00%	0.00%	14,295	$19,006	9.80%
Mooers, NY	0	300	138	0	0	4.50%	4.20%	13,626	$21,589	8.60%
Intl Falls, MN	0	489	0	0	0	0.00%	0.00%	13,370	$11,464	-
Orient, ME	0	277	39	0	0	4.50%	4.40%	12,773	$13,685	12.60%
Ambrose, ND	0	284	0	0	0	0.00%	0.00%	10,024	$6,430	13.90%

Table 4-6: RE Solutions that Minimize Life Cycle Cost (without incentives)

	Wind Capacity (kW)	Solar Vent Preheat Area (ft^2)	Solar Water Heating Area (ft^2)	Biomass Gasifier Size (M Btu/h)	Biomass Gasifier Cogen Size (kW)	Daylighting non-Office Skylight/Floor Area Ratio	Daylighting Office Skylight/Floor Area Ratio	Total CO_2 prevented (lbs/yr)	Total Initial Cost ($)	Return on investment (%)
St. John ND	0	269	0	0	0	0.00%	0.00%	9,001	$5,563	12.20%
Alburg Springs, VT	0	145	72	0	0	4.60%	4.30%	8,710	$13,545	9.40%
Highgate Springs 3, VT	0	199	0	0	0	4.40%	4.00%	8,463	$18,285	10.30%
RR Inspection, TX	0	0	0	0	0	4.50%	4.50%	7,666	$3,210	9.40%
Beebe Plain, VT	0	161	0	0	0	4.50%	4.20%	7,601	$7,923	12.40%
Oroville, WA	0	289	0	0	0	0.00%	0.00%	6,889	$0	44.80%
Jamieson, NY	0	111	24	0	0	4.90%	5.20%	4,142	$5,097	14.60%
Milltown ME	0	50	63	0	0	4.50%	4.50%	4,026	$7,992	7.20%

*Size 0 means the RE technology could not be sized to yield a return on investment greater than the discount rate of the life-cycle analysis (4.6 percent). PV, Solar Thermal, and Solar Thermal Electric were not cost effective at any LPOE site without incentives.

Note that each technology is recommended as part of the optimized solution for a site, and these sizes minimize life-cycle costs. In other words, it is possible for an LPOE site to cost effectively generate more RE than the optimized solution indicates, but the life cycle costs would be higher.

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5. Conclusions

The purpose of this detailed analysis of the 119 LPOE sites managed by GSA is to identify the cost-effective RE technologies that can support the accomplishment of GSA's energy goals at the national, regional, and site levels.

The analysis results will help GSA prioritize RE projects for maximum progress toward achieving RE goals while being financially prudent. Highlights of the aggregated results include the following:

- At 109 of the 119 LPOE sites managed by GSA, optimized mixes of the RE technologies can be cost-effective without financial incentives. Based on a 25-year life-cycle analysis, the overall ROI for these RE solutions is 11.8 percent.

- Implementing all 109 cost effective RE solutions can provide more than 15 percent of the total energy used at the 119 LPOE sites in the study. In terms of individual LPOE sites, RE solutions can provide at least 30 percent of on-site power requirements for 28 of them.

- Implementing all of the cost-effective RE solutions identified will reduce CO_2 emissions by more than 24.38 million pounds each year. That is the equivalent of removing more than 2,100 passenger cars from the road.

Based on the optimized solutions from this analysis, the RE generated is a relatively small percentage of the total current energy use at these LPOE sites. While implementing these solutions would be a solid step towards achieving net zero energy buildings – where RE uses is equal to total energy use – GSA may consider a follow on study that analyzes locations with the best opportunity for reaching net zero instead of minimizing life cycle costs.