ARGONNE NATIONAL LABORATORY

Site Sustainability Plan

December 2010

A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

U.S. DEPARTMENT OF ENERGY

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Prepared for U. S. Department of Energy

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List of Acronyms

A&E	Architectural & Engineering
AFV	Alternative-fuel vehicles
AHU	Air Handling Unit
ALCF	Argonne Leadership Computing Facility
APS	Advanced Photon Source
Btu/GSF	British thermal units per gross square foot
C&D	Construction and demolition
CEM	Certified Energy Manager
CHP	Combined Heat and Power
CIS	Computer Information System
CMS	Chemical Management System
CNM	Center for Nanoscale Materials
CO_2	Carbon dioxide
D&D	Decontamination and decommissioning
DOE	Department of Energy
E4	Expert Energy Efficiency Evaluations
ECM	Energy conservation measures
EIS	Energy Information System
EISA	Energy Independence and Security Act
EM	(DOE's) Office of Environmental Management
EO	Executive Order
EPA	Environmental Protection Agency
EPCRA	Energy Planning and Community Right to Know Act
ESB	Energy Sciences Building
ESPC	Energy Savings Performance Contract
FEMP	Federal Energy Management Program
FIMS	Facilities Information Management System
FMS	(Argonne's) Facilities Management and Services Division
FY	Fiscal year
gal/GSF	Gallon per gross square foot
GHG	Greenhouse gas
GSA	General Services Administration
GSF	gross square foot
HEMSF	High energy mission specific facilities
HPSB	High performance sustainable buildings
HRSG	Heat recovery steam generator
HVAC	Heating, ventilating, and air conditioning
IGPP	Institutional General Plant Projects
ILA	Industrial, landscaping, and agricultural
ISSF	Interim Scientific Supercomputing Facility
LED	Light-emitting diode
LEED	Leadership in Energy and Environmental Design
LOM	Laboratory/office module
MDL	Materials Design Laboratory
MR	Major repair
MT	Metric tons
MWh	Megawatt hours
NEPA	National Environmental Protection Act
NREL	National Renewable Energy Laboratory
NO_x	Nitrogen oxides
ODS	Ozone-depleting substance

P2	Pollution prevention
PPOA	Pollution prevention opportunity assessment
PPTRS	Pollution Prevention Tracking and Reporting System
R&D	Research and development
REC	Renewable energy credit
ROI	Return on investment
SAMM	Sub-Angstrom Microscopy and Microanalysis Facility
SC	DOE Office of Science
SF_6	Sulfur hexafluoride
SMR	Small modular reactor
SSP	Site Sustainability Plan
SSPP	Strategic Sustainability Performance Plan
SSTT	Site Sustainability Transformation Team
TCS	Theory and Computing Science
T&D	Transmission and distribution
VFD	Variable Frequency Drive
ZGS	Zero Gradient Synchroton

Executive Summary

This draft Site Sustainability Plan (SSP) outlines an aggressive strategy to reduce greenhouse gas (GHG) emissions at Argonne National Laboratory by over 37%. Almost 95% of Argonne's 339,000-ton baseline GHG emissions comes from three sources: purchased electricity, on-site steam production, and sulfur hexafluoride (SF_6) use. Key SSP strategies include a new Combined Heat and Power (CHP) plant, an intranet-based Energy Information System, SF_6 leak detection and recovery systems, and construction of new, energy-efficient buildings.

Despite these initiatives, Argonne's main challenge remains the managing of sustainability goals during a period in which the Laboratory is undergoing significant growth. Since the 2008 GHG baseline was established, four major facilities -- the Theory and Computing Sciences (TCS) Building, the Ricketts Laboratory, the Advanced Leadership Computing Facility (ALCF), and the Sub-Angstrom Microscopy and Microanalysis (SAMM) Facility, have come on line. Even with investment in numerous energy efficiency projects in the last two years, electricity use has increased due to the power demand of these new facilities. Adding to this growth will be near-term startups of the new Central Chilled Water plant, Energy Sciences Building (ESB), Advanced Protein Crystallization Facility, and Materials Design Laboratory (MDL), as well as the expansion of the Argonne Leadership Computing Facility and start-up of exascale computing facilities.

To balance this growth, Argonne is both retrofitting existing facilities and demolishing unnecessary legacy facilities that, although unoccupied, still require heat and power for safety and security reasons. Buildings 301 and 330 were recently demolished and Building 310 will be demolished this fiscal year. Several nuclear facilities are presently being de-inventoried in preparation for deactivation and demolition. Critical to the success of Argonne's sustainability plan, is the Laboratory's ability to obtain continued support from the U.S. Department of Energy's (DOE) Office of Environmental Management (EM) for decontamination and decommissioning (D&D) of legacy facilities. In the interim, Argonne is evaluating the effective consolidation of operations so that entire buildings and/or wings can be placed in a cold-shutdown status.

Clearly, a transformational energy strategy is required to balance this growth -- particularly from exascale computing facilities, which will more than double the Laboratory's current power demand. Argonne has created a Site Innovation Team and engaged its top researchers to develop this strategy. The team is focusing on clean energy technologies that can be deployed over the next 10 years as the Laboratory's power needs increase.

Achieving our sustainability goals requires all employees to contribute. A Sustainability Program Office (see Section 4) has been set up under the direction of Dr. Paul Kearns, Deputy Laboratory Director for Operations and Chief Operations Officer. Dr. Mark Peters, Chief Research Officer and Deputy Lab Director for Programs, has been appointed as Sustainability Innovation Officer. A team specifically devoted to developing employee awareness and involvement is included in the five major sustainability program teams. Significant employee outreach activities are planned to create interest, inspire employee-generated ideas, and adopt sustainable behavior.

Argonne has developed a strategy to meet all goals from Executive Order (EO) 13514, *Federal Leadership in Environmental, Energy, and Economic Performance.* Great progress has been made already. In the areas of petroleum reduction and use of alternative fuels, targets have been well exceeded. Through an extensive water recycling effort, Argonne has reduced potable water use by 17% in just 3 years. Argonne has also reduced sulfur hexafluoride emissions, a key contributor to global warming, by nearly 75% since the 2008 baseline year.

The table below summarizes Argonne's current progress towards EO goals.

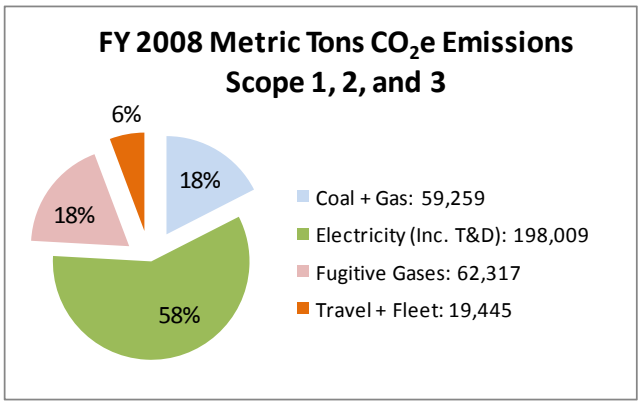
DOE Goal	Argonne FY10 Performance Status	Major Planned Actions
28% Scope 1 & 2 GHG reduction by FY 2020 from FY 2008 baseline	11.3% reduction	CHP plant, SF_6 recovery, renewable energy systems, etc.
30% energy intensity reduction by FY 2015 from a FY 2003 baseline (goal subject buildings only)	15.7% reduction	Site-wide ESPC, in-house energy projects, CHP, steam loss reductions, Advanced Photo Source (APS) lighting upgrade, building retro-commissioning; energy audits, heat recovery systems
7.5% of site's annual electricity consumption from renewable sources by FY 2010	Will be met via RECs purchase until on-site sources are developed	Investigating bio-fuel steam production and high-conductance wind turbines
Every site to have at least one on-site renewable energy generating system by FY 2010	Met	Installed solar/wind street lamps
10% annual increase in fleet alternative fuel consumption by FY 2015 from FY 2005 baseline	Met – over 75% increase already achieved	Continued use of alternative-fueled vehicles (AFVs)
2% annual reduction in fleet petroleum consumption by FY 2015 from FY 2005 baseline	Met – over 81% reduction already achieved	Continued use of AFVs, hybrids, and electrics
75 percent of light duty vehicle purchases must be AFV by FY 2015	Met – all purchases are AFVs	Continued acquisition of AFVs as fleet changeover occurs
Advanced metering for electricity (by October 2012), steam, and natural gas (by October 2016); standard meters for water	Pilot building completed in FY 2010	Expansion of pilot; development of Energy Information System (EIS); installation of more advanced meters
Cool roofs, unless uneconomical, for roof replacements unless project already has CD-2 approval.	Met – only cool roofs specified. 10% of roofs retrofitted	All future new buildings will have cool roofs; additional 15% of roofs to be replaced by FY 2015
DOE facility energy managers to be Certified Energy Managers by September 2012.	Met - four staff members have CEM.	Additional professional training and continuing education
Sulfur hexafluoride (SF_6) capture program by September 2012.	73% reduction achieved. Additional recovery systems to be purchased	Install SF_6 recovery on large systems; continue development of leak detection and repair procedures
13% Scope 3 GHG reduction by FY 2020 from a FY 2008 baseline	1.7% increase (caused by an increase in number of employees)	Expand use of videoconferencing
All new construction and major renovations greater than $5 million to be LEED® Gold	All new buildings designed to meet LEED Gold	All new buildings to meet or exceed
Meet high-performance and sustainable building (HPSB) guiding principles if less than $5 million	All new buildings designed to meet guiding principles	All new buildings to meet or exceed
15% of existing buildings larger than 5,000 gross square feet (GSF) to be compliant with the five guiding principles of HPSB by FY 2015	Plan to meet – 3% of existing buildings comply with Guiding Principles	Continue focus on Laboratory Office Modules (LOMs) at APS
20% potable water intensity reduction by FY 2015 from a FY 2007 baseline.	At 18.9% reduction through FY 2010	Water recycling, alternate blowdown cycles
20% water consumption reduction of industrial, landscaping, and agricultural (ILA) water by FY 2020 from a FY 2010 baseline	N/A (FY 2010 is baseline year)	Cooling water recycling; continued use of native landscaping

1.0 Introduction

Argonne Green Lab Challenge

Turning Ideas into Actions

Argonne's FY 2008 carbon baseline was 339,029 metric tons. Purchased power (both direct emissions and transmission losses) represents 58% of the footprint. Fugitive emissions (primarily sulfur hexafluoride - SF_6) comprise the next largest component at 18%. Coal and natural gas combustion for steam production is approximately 18%. The remaining 6% is related to transportation – most of which is attributable to employee commuting and business air travel.



Argonne is developing strategies and taking actions to meet or exceed all Executive Order (EO) goals. In EO 13514, Federal Leadership in Environmental, Energy, and Economic Performance, President Obama calls on federal agencies to set a shining example of sustainability for the rest of the nation by improving environmental, energy, and economic performance, and to achieve targeted reductions in our greenhouse gas (GHG) emissions by 2020. The highest risk/opportunity areas are affordable on-site renewable energy, energy intensity, and growth of High Energy Mission Specific Facilities (HEMSF). We are leveraging our world-class competencies in energy research and development (R&D) and enlisting our top scientists to develop innovative solutions to these problems. For renewable energy, researchers are looking at the latest in high- conductance wind turbines, solar power, geothermal energy, and biofuel combustion.

Through FY 2010, Argonne achieved a 15.7% energy intensity reduction for goal-subject buildings. However, considerable funding ramp-up is required to meet the 30% FY 2015 goal. Finally, the highest risk lies in our growth potential. Power demands are expected to double or triple in the next seven years as Argonne builds out exascale computing facilities. Although these facilities are exempt from energy intensity requirements, meeting GHG reduction goals will require innovative clean or renewable energy solutions.

Argonne's Site Sustainability Program is divided into five key focus areas:

- Transportation
- Energy and Water Conservation
- Renewable and Clean Energy
- Pollution Prevention (P2)
- Employee Involvement

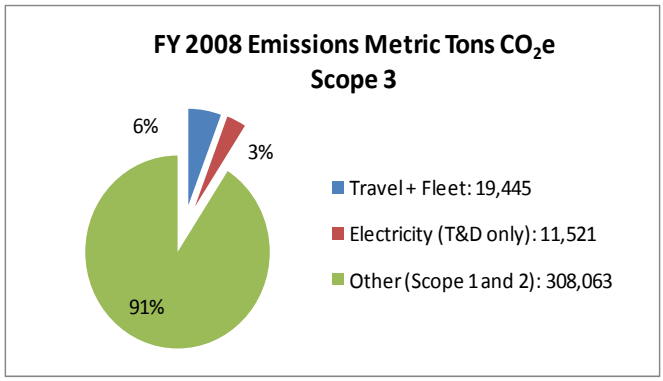
The Laboratory developed overall goals within each focus area that support EO 13514 goals and Argonne's commitment towards a sustainable campus. Major strategies and actions were then developed that when executed, provide the means for goal achievement.

Area 1 – Transportation

Goals and Strategies

1. Green the fleet
   a. Cut petroleum use by 2% annually
   b. Changeover to alternative-fueled vehicles

2. Promote a healthy work environment by facilitating walking and biking.



3. Cut emissions from employee transportation by 15%
   a. Facilitate carpooling and low-emission vehicles
   b. Reduce carbon footprint from employee business travel

Table 1-1: Transportation Strategies

Action	Plan	Status	GHG Reductions (Metric tons)
Lease and purchase electric vehicles	Maximize leasing as cars become available through General Services Administration (GSA).	Purchased five small "Neighborhood" electric vehicles in FY 2010 for on-site use	20
Reduce emissions from medium and heavy duty vehicles	Monitor industry developments; switch to biodiesel mixes.	Various ethanol/diesel fuel mixes being introduced	70
Lease hybrid vehicles	Add 10 more hybrids to fleet in next two years	Five hybrids added to fleet in FY 2010	25
Expand Bike Share program	Continue partnership with Chicago Transportation Alliance.	Fleet size increased to 110 bicycles in FY 2010	50
Improve biking conditions	Continue practice of widening roads to promote safe bike travel	19% of paved roads widened	N/A
Encourage walking and biking	Continue participation in Active for Life competition and promotion of "Bike to Work"	Over 740 participants (20% of workforce) in FY 2010 kickoff year	N/A
Expand use of videoconferencing	Evaluate current use and capabilities; develop plan to expand services and use	Begin evaluation in FY 2011	705
Create walking campus	Reduce the need for intra-building car travel	Campus master plan developed	N/A
Promote use and reporting of high efficiency vehicles	Create mechanism for reporting and promoting use of high-efficiency vehicles and car pooling	Preferred parking established at two buildings	1,708[1]
		Total Target Reduction	2,578

[1] The Laboratory assumes there will savings in employee commute emissions from greater availability, government mandates, and market forces for high-fuel-efficiency vehicles.

Area 2 – Energy and Water Conservation

Water Conservation Goal and Strategies

1. Reduce potable water use 20% by 2020 (from 2007 baseline)
2. Reduce industrial water use 20% by 2020 (from 2010 baseline)
3. Maximize use of recycled water

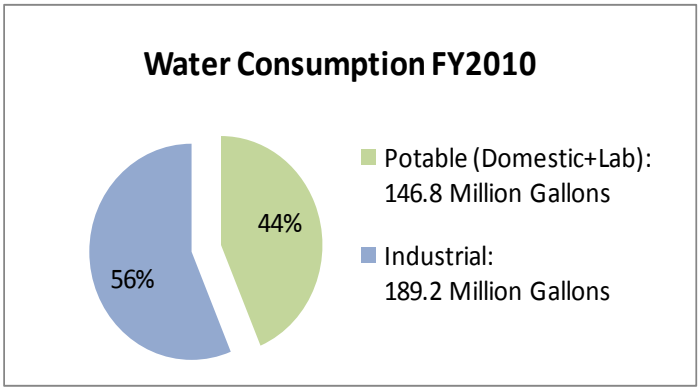


Table 1-2: Water Conservation Strategies

Action	Plan	Status	Water Reduction (million gal)
Use low-flow fixtures	Continue specifying for all new facility and renovations	Only minimal number of fixtures converted (<5%)	6
Repair Steam Traps (external leaks)	Expand program to build steam traps; evaluate use of real time monitoring tied to campus Building Automation System	Major outdoor steam traps completed in FY 2010	10
Recycle cooling water	Complete re-plumbing to recycle cooling water used in numerous buildings	Six projects completed in FY 2010	27
Eliminate once-through cooling water	Eliminate additional once-through cooling water by adding systems to a central chilled-water loop	Ten or more projects scheduled from FY 2011 to FY 2015	30
Implement tighter water chemistry and blowdown control	Reduce industrial makeup water needs through better water chemistry and reduced blowdown cycles	Begin evaluation in FY 2011	18.5
		Total Target Reduction	91.5

Green Building Goals and Strategies

1. Ensure 15% of buildings greater than 5,000 sq ft meet Guiding Principles by FY 2015
2. Construct all new buildings over $5 million to meet Leadership in Energy and Environmental Design (LEED) Gold certification or greater
3. Meet Guiding Principles for new construction under $5 million
4. Effectively consolidate operations and research to maximize cold shutdown of older buildings as new, energy-efficient buildings come on line.

Current buildings over 5,000 sq ft	72
Total buildings over 5,000 sq ft (FY 2015)	77
15% requirement	12
Current buildings meeting requirement	2
Additional buildings needed	10

Table 1-3: Green Buildings Strategies

Action	FY	Plan	Status	Building Count
Existing Buildings				
Lab/Office Modules	FY 2014	HPSB	Finalize study in FY 2012; complete retrofits by FY 2014	2 - 6
Center for Nanoscale Materials	FY 2011	LEED Silver	Application submitted and accepted	1
New Construction (>$5 mil)				
Energy Sciences Building (ESB)	FY 2013	LEED Gold	Design underway; LEED assessment complete and on target	1
Materials Design Laboratory (MDL)	FY 2013	LEED Gold	Preliminary design completed to meet criteria	1
Advanced Protein Crystallization Facility	FY 2014	LEED Gold	Conceptual planning underway	1
Advanced Photon Source (APS) – Early Assembly Building	FY 2015	LEED Gold	Conceptual planning underway	1
APS – Long Beamline	FY 2015	LEED Gold	Conceptual planning underway	1
New Construction (<$5 mil)				
Central Chilled Water Plant	FY 2011	HPSB / LEED	Construction underway	1
Combined Heat and Power Plant	FY 2013	LEED Silver	Preliminary design meets criteria	1
			Total Target Reduction	10 -14

Electricity Intensity Goals and Strategies

1. Reduce energy intensity 30% in goal-subject buildings by 2015
2. Reduce energy use 20% in excluded facilities to facilitate GHG reduction by 2020
3. Reinvest utility cost savings in additional energy projects
4. Create a platform for intelligent building and data center management

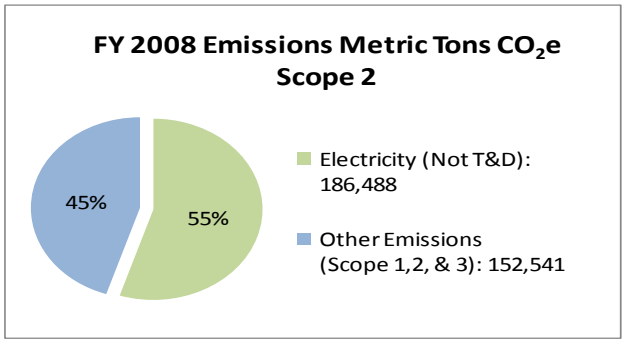


Table 1-4: Electricity Intensity Reduction Strategies

Action/Area	Plan	Status	GHG Reductions (Metric tons)
Site-wide Award Energy Savings Performance Contract (ESPC)	Start project in FY 2012 for FY 2013 award	Evaluating ECMs requiring larger capital investment; target $5 to $10 million investment	4,000
In-house energy savings program	Complete 10 to 15 projects annually based on return on investment (ROI)	FY 2011 program funded at $612K	11,000
APS lighting	Install energy-efficient lighting in APS	Project scoped out; planned execution in FY 2011 through FY 2014	400
Consolidate data centers	Complete ROI analysis	Plan developed at estimated cost of $500,000	TBD
Energy reduction software for desktops	Improve desktop power usage	Pilot program underway	150
Install advanced metering	Upgrade metering to optimize building and data centers operations	Pilot completed at mid-size office building; developing specifications for campus-wide system	3,000
Building retro-commissioning	Retro-commission five high energy use buildings	Applied for Federal Energy Management Program (FEMP) assistance program	1,600
Cool roofs	Continue cool/white roof changeover	10% of retrofits completed; additional 15% planned by FY 2015	300
		Total Target Reduction	20,450

Steam Reduction Goals and Strategies

1. Support energy intensity goals through efficient steam generation
2. Incorporate use of renewable fuel for steam production (see Renewable Energy Section)
3. Minimize losses in condensate lines and steam traps
4. Minimize heat loss in buildings and install heat recovery systems

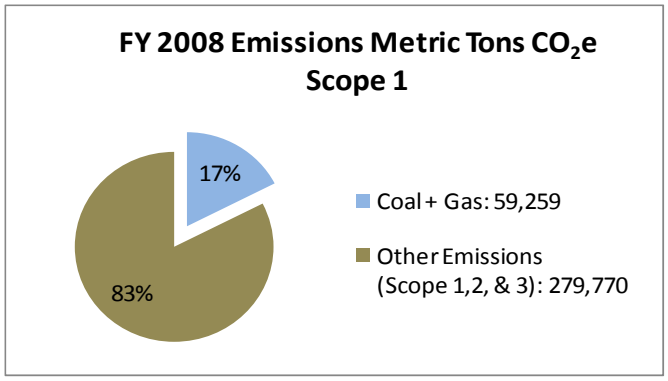


Table 1-5: Steam Reduction Strategies

Action	Plan	Status	GHG Reductions (metric tons)
Build Combined Heat and Power Plant	ESPC in FY 2011	Expect plant to be operational by FY 2013[2]	35,000
Complete steam plant energy assessment	Complete energy audit of existing steam plant	Study completed – awaiting final report	500
Repair steam traps	Expand program to building steam traps; evaluate use of real-time monitoring tied to Metasys®[3]	Major outdoor steam traps replaced in FY 2010	800
Develop geothermal energy systems with heat recovery	Evaluate heat recovery systems on large power users such as APS and high performance computing centers	Preliminary analysis completed; conduct engineering study in FY 2011	TBD
		Total Target Reduction	36,300

[2] Note: Many of the projects included in the electricity or steam tables will have savings in both areas. For simplicity, projects are listed in the table where the majority of savings are expected.

[3] Argonne uses the Johnson Controls, Inc., Metasys® as its buildings' automation and control system.

Area 3 - Renewable and Clean Energy

Goals and Strategies

1. Meet or exceed 7.5% on-site renewable energy production
2. Develop large-scale clean energy sources to support exascale computing and other scientific program growth
3. Purchase renewable energy credits to promote renewable energy technology

Table 1-6: Renewable and Clean Energy

Action	Plan	Status	GHG Displacement (metric tons)
Develop bio-fuel combustion capability	Continue efforts to use bio-fuel in solid fuel boiler and/or new CHP plant.	Solid-fuel boiler tests successful; however, renewable fuel market is cost-prohibitive at present	5,000
Create mid-scale renewable energy capability	Evaluate high-conductance wind turbines	Have met with vendors; may conduct feasibility study in FY 2011	15,000
Purchase Renewable Energy Credits	Purchase credits to meet balance of goal versus on-site production	Purchase will be made in FY 2011 for 7.5% of projected electrical power use	27,973
Small-scale fuel cells	Install small-scale (5, 10, and 15kW) units at three locations	Expect operational in FY 2012	300
Medium-scale fuel cells	Install mid-size (400 kW) unit at the CNM	Feasibility study completed; evaluate ROI in FY 2011	2,500
Large-scale solar array with energy storage	Evaluate the potential for large-scale solar to offset programmatic growth	Initial siting evaluation completed to assess available land options	TBD
Develop large-scale clean or renewable energy source	Continue to explore Purchase Power Agreements or potential on-site or nearby project	Drafted white paper to propose change to use off-site clean power sources for GHG reduction credit	TBD
		Total Target Reduction	>50,000

Area 4 – Pollution Prevention

Goals and Strategies

1. Reduce SF_6 emissions by 90% from FY 2008 levels
2. Insert sustainability requirements in 95% of contracts
3. Use established P2 program to support sustainability goals
4. Divert at least 50% of non-hazardous solid-waste construction and demolition (C&D) debris from landfills by FY 2015

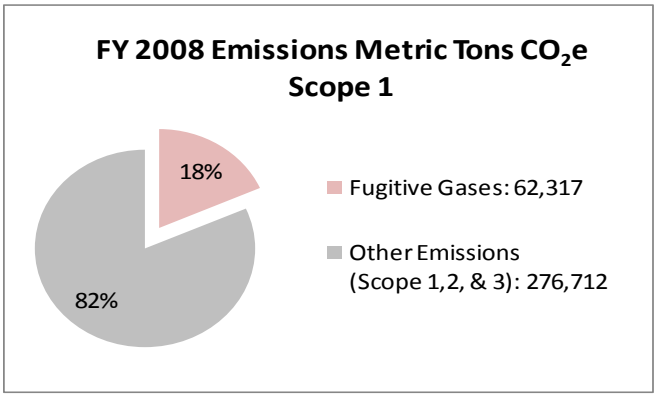


Table 1-7: Pollution Prevention Strategies

Action	Plan	Status	GHG Reductions (metric tons)
Capture SF_6 fugitive emissions	Operate leak detection and recovery systems on all sources by FY 2013	Team established and recovery systems being chosen; will begin procurement in FY 2011	54,036
Sustainable acquisition	Incorporate Sustainability Mega-Clause into all new contracts beginning January 1, 2011	Procurement department developing procedures to implement	N/A
Pollution prevention	Continue Pollution Prevention Opportunity Assessment Program (PPOA)	Eight PPOAs scheduled for FY 2011	TBD
Waste reduction	Numerous events and activities are planned; See Table 2-11 for details.	See Table 2-11	N/A
		Total Target Reduction	54,036

Area 5 – Employee Awareness

Goal and Strategies

1. Engage entire workforce in meeting sustainability goals
   a. Use programmatic researchers for sustainability planning
   b. Encourage "sustainable" personal behavior by all employees

2. Actively promote sustainability as a core value and program
   a. Create and execute a long-term communication plan
   b. Demonstrate senior leadership commitment
   c. Include sustainability considerations in budget decisions and project selection
   d. Integrate sustainability program and Environmental Management System (EMS)

Table 1-8: Employee Awareness Strategies

Action	Plan	Status
Strategic Transformation Teams	Use programmatic scientists and engineers to develop transformative ideas for campus GHG reduction	Teams are set up and actively generating proposals and beginning work on projects
Sustainability Communications Plan	Develop multi-faceted plan to communicate Argonne program and solicit involvement	Communications plan, entitled - "Green Lab Challenge: Turning Ideas into Action," completed
GHG Footprint Reduction Contest	Start intra-division and intra-building contests for GHG reduction	Expect to launch in early 2011
Sustainability WebPage	Capture sustainability program efforts in new web page for internal and external access	Expect to stand up site during January 2011
Sustainability Training	Expand integration of sustainability concepts into employee awareness training	Preliminary planning underway
GHG and EO Goal Visibility	Integrate metering data into energy/GHG "dashboards"	Team formed and initial concept for dashboards developed; funding allocated in FY11 for development of campus Energy Information System (EIS)

Summary

Table 1-9 below summarizes Argonne's initial GHG reduction target of over 37%. Additional details on these strategies and actions are provided in Section 2, Goal Performance Review and Plans.

Table 1-9: Major Strategic Initiative Summary

Focus Area	FY 2008 Emissions (MT CO_2)	SSP Reductions (MT CO_2)	Overall GHG Target Reduction (percent)
Transportation (Scope 1 and 3)	19,445	2,578	13.3
Steam Production (Gas and Coal)	59,259	36,300	61.2
Electricity (Scope 1 and 3)	198,009	20,450	10.3
Fugitive Emissions (F-Gases, Landfill, and Wastewater)	62,317	54,036	86.7
Renewable and Clean Energy	0	13,987 (credit)	7.5
Total	**339,030**	**127,350**	**37.5**

Section 2 of the SSP provides more details on these initiatives per the required DOE template. *Table 1-10* provides a crosswalk of EO 13514 and DOE SSPP components to Argonne's Sustainability Program focus areas:

Table 1-10: Executive Order/SSPP Component	
Focus Area	**Executive Order/SSPP Component**
Transportation	Petroleum Use Reduction for Fleet Vehicles Alternative-Fuel Vehicles for Fleet Use Employee Business Travel (Air and Ground) Employee Commuting
Energy and Water Conservation	Energy Intensity Cool/White Roofs Potable Water Reduction Industrial Water Reduction Data Center Efficiency Metering LEED/HPSB for New Construction/Major Renovation Guiding Principles for Existing Buildings
Renewable and Clean Energy	On-Site Renewable Electricity Use Increase Renewable Energy Consumption GHG Reductions
Pollution Prevention	Electronics Stewardship Pollution Prevention and Waste Elimination Sustainable Acquisition SF_6 Emissions Reduction Storm Water Management
Employee Involvement	Training Site Innovation Regional and Local Planning Comprehensive GHG Inventory

2.0 Goal Performance Review and Plans

2.1 Scope 1 and 2 Greenhouse Gas Reduction

2.1.1 Energy Intensity Reduction

The energy intensity reduction goal is 30% by the end of FY 2015, relative to FY 2003 baseline, for goal-subject buildings (Figure 1-1).

2.1.1.1 Performance Status

Many Energy Conservation Measures (ECMs) are completed or underway. While Argonne has concentrated efforts in goal-subject buildings, work has been performed throughout the campus because of the Laboratory's commitment to a smaller carbon footprint.

Over 54% of electricity use is at accelerators and data centers that have been exempted from energy intensity reduction goals (Figure 2-2). Due to the high percentage of buildings with power loads driven by scientific equipment, only about 30% of Argonne's overall electricity use is considered "goal-subject." Argonne is slightly behind pace in meeting energy intensity goals. By the end of FY 2010, the energy intensity ratio was reduced by 15.7%, versus a targeted 17.5% (see Figure 2-1). Overall power consumption (both goal subject and goal excluded) is shown in Figure 2-3.

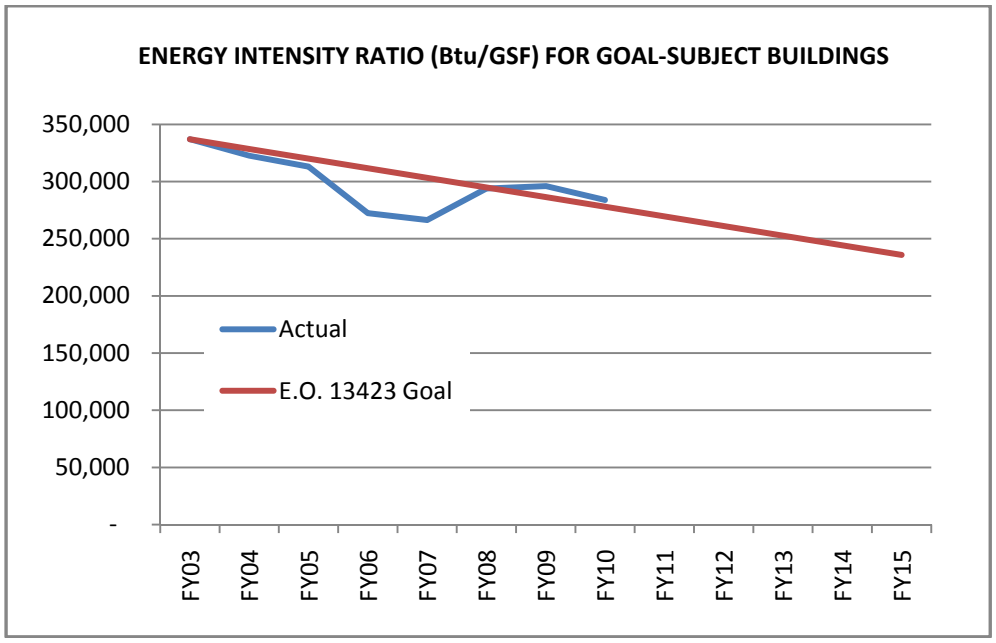


Figure 2-1: Energy Intensity Ratio

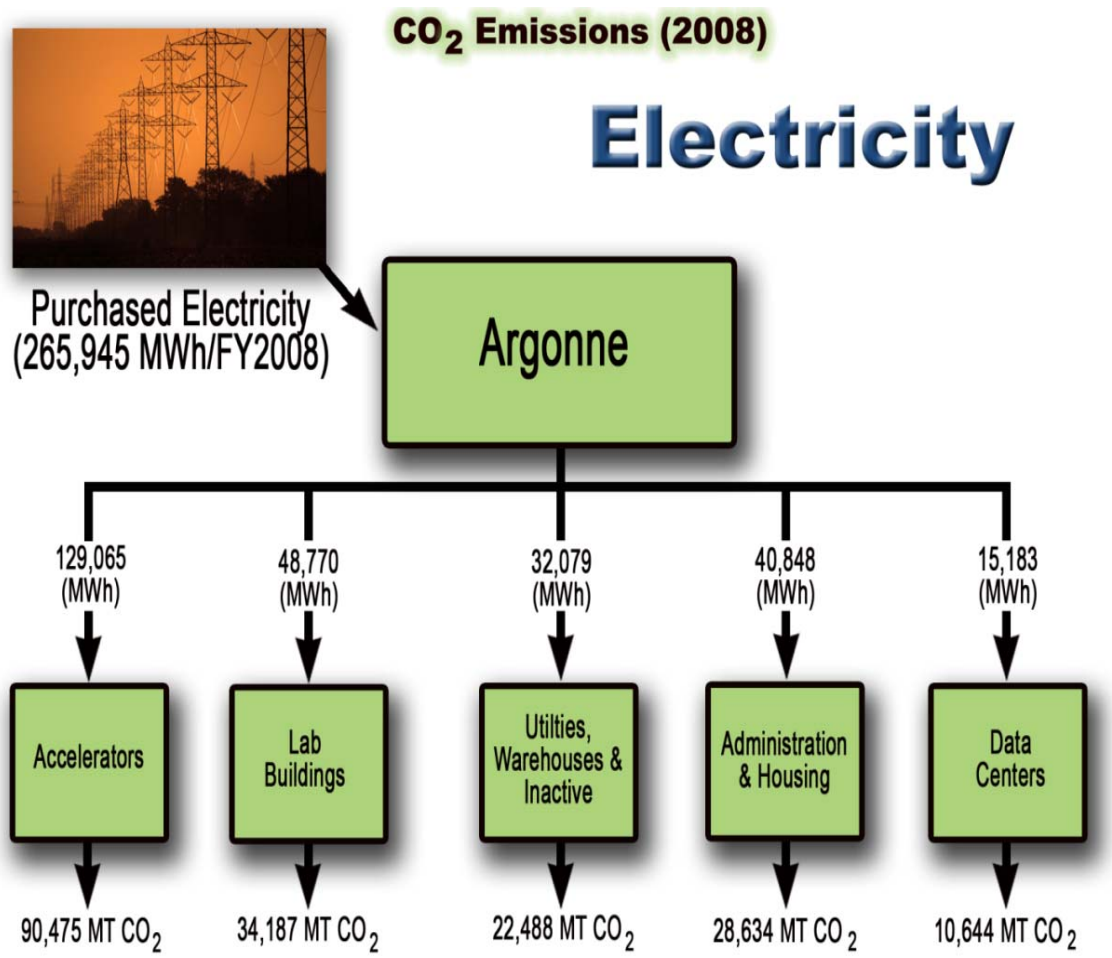


Figure 2-2: Electricity Usage at Argonne National Laboratory

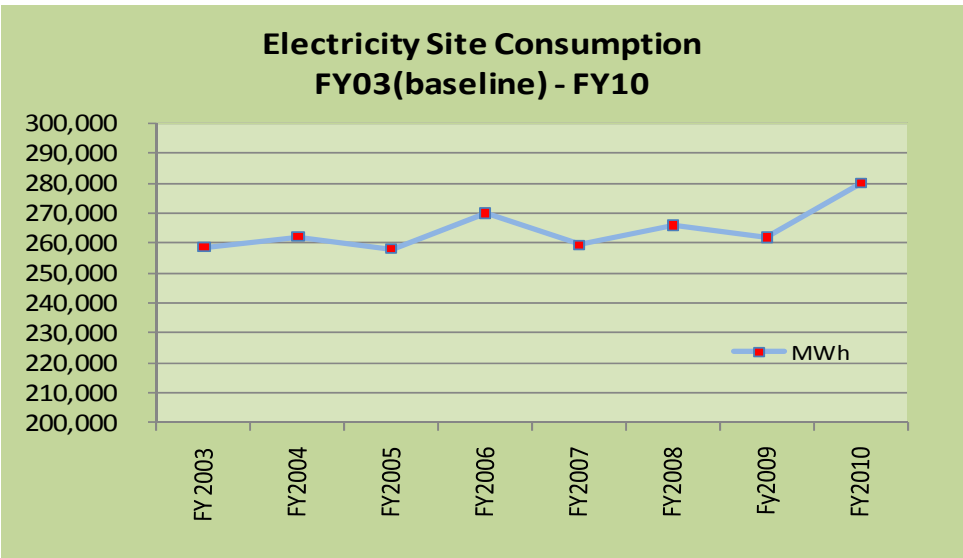


Figure 2-3: Site Electrical Energy Consumption per Fiscal Year

Argonne achieved these reductions via two major strategic programs – Energy Savings Performance Contracts (ESPCs) and its In-House Energy Savings Reinvestment Program. Argonne has successfully utilized ESPC contracting for several years. *Table 2-1* shows the energy conservation measures, energy savings, and cost savings from the Lab's three current ESPC projects.

Table 2-1: Energy Conservation Measures, Energy Savings, and Cost Savings

ESPC 1	Energy Savings (MBtu/yr)	Cost Savings($/yr)
Building 201 – Upgrade Controls	1,040	$45,243
Building 350 – Reduce Unoccupied Outside Air	8,867	$57,267
Buildings 314/315/316 Lighting Upgrade	810	$13,839
Building 350 Lighting System Upgrade	719	$13,186
Upgrade Steam Pipe Insulation	28,808	$193,560
Building 315 VFD Installation on S-3 System	2,938	$21,141
	43,182	**$344,235**
ESPC 2		
Coal Fired Boiler Upgrade	19,197	$595,785
ZGS Area Chiller Replacement	4,374	$80,550
FMS Extended Architecture Upgrade	48	$37,079
APS Storage Ring Heat Recovery	9,845	$82,676
300 Series Buildings – Lighting Improvements	3,356	$60,647
200 Series Buildings – Lighting Improvements	9,193	$177,953
Building 200 K Wing Window Replacement	55	$873
Site Wide Condensate Return Improvements	6,306	$68,290
APS Storage Ring Pumps/VFDs	6,830	$122,819
	59,204	**$1,226,670**
ESPC 3		
APS Free Cooling and Metasys Upgrade	7,984	$179,417
APS Experimental Hall AHU Modifications	14,738	$141,502
APS LOM AHU Heat Reclamation	7,251	$68,194
APS Lighting Upgrades	1,646	$36,995
APS Lighting Controls Upgrade	1,677	$37,683
	33,296	**$463,791**
Grand Total ESPC	**135,682**	**$2,034,696**

Beginning in late FY 2008, Argonne created its in-house Energy Savings Reinvestment Program initiative to complement the ESPC program. Under this initiative, the Laboratory's maintenance foremen and engineering team identify, evaluate, and prioritize energy conservation projects. Projects are completed using Argonne maintenance mechanics or small contracts to achieve quick savings. Savings are measured, verified, and reported to Argonne's budgeting office which, in turn, then provides recurring funding equivalent to the amount of utility cost savings. This funding is then reinvested in additional energy savings projects.

Ongoing Project Energy and Cost Savings for In-house Program	
Annual Energy Savings	39,106 MBtu/yr
Annual Water Savings	15,322 KGal/yr
Annual Cost Savings	$507,952

By the end of FY 2010, the program had generated over $500,000 per year in annual savings. The program was recognized by both the federal "GreenGov Presidential Award" and a DOE "Federal Energy and Water Management Award" at ceremonies in Washington, D.C. on October 7, 2010. *Table 2-2* provides a summary of completed in-house energy and water projects.

Table 2-2: In-house Energy and Water Projects

Date Applied	Project Title	Electricity Savings (kW/yr)	Electricity Savings (mmBtu/yr)	Electricity Savings ($)	Steam Savings (mmBtu/yr)	Steam Savings ($)	Total Energy Savings (mmBtu/yr)	Annual Savings ($)
Oct-08	Exit Sign Installation FY08	26,017	89	1,996			89	1,996
Oct-08	Boiler House VFD Installation	90,000	307	6,903			307	6,903
Oct-08	Boiler House Air Compressor Installation	35,808	122	2,746			122	2,746
Oct-08	Building 203 Condensate Return Project		0	0	4,297	$ 41,082	4,297	50,707
Oct-08	Building 203 Cooling Tower Project	138,963	474	10,658			474	10,658
Apr-09	Exit Sign Installation First Half FY09	14,437	49	1,107			49	1,107
Apr-09	Building 201 Conference Room Dimmer Panel	405	1	249			1	249
Apr-09	Building 366 Lighting Upgrade	210,240	717	16,125			717	16,125
Oct-09	Tower 42 Heating System		0	0	16,751	$ 136,213	16,751	141,973
Oct-09	Buildings 314-316 Condensate Return		0	0	884	$ 7,426	884	10,128
Oct-09	Building 201 Condensate Return		0	0	133	$ 1,116	133	1,522
Oct-09	Exit Sign Installation Second Half FY09	46,100	157	3,536			157	3,536
Oct-09	Building 369 Lighting Upgrade	217,268	741	16,664			741	16,664
Oct-09	Building 364 Pump VFD	360,945	1,232	27,684			1,232	27,684
Oct-10	HVAC Unit Replacement	39,113	133	3,000			133	3,000
Oct-10	Install Occupancy Sensors	73,357	250	5,626			250	5,626
Oct-10	HVAC Controls Upgrade	277,966	948	21,320	3,000	$ 28,680	3,948	50,000
Oct-10	Cooling Tower Modernization	664,875	2,269	50,996			2,269	50,996
Oct-10	LED Emer Exit Lights- Phase 3 (Bldgs 200, 202, 203)	77,025	263	5,908			263	5,908
Oct-10	Replace T-12 with T5 Lamps in High Bays	96,290	329	7,385			329	7,385
Oct-10	Replace T-12 with T5 Lamps in High Bays	270,544	923	20,751			923	20,751
Oct-10	Replace T-12 with T5 Lamps in High Bays	108,379	370	8,313			370	8,313
Oct-10	Exterior Lights-entrance	4,555	16	349			16	349
Oct-10	Replace Air Compressor	89,602	306	6,872			306	6,872
Oct-10	Cooling Tower Replacement 350	24,600	84	1,887			84	1,887
Oct-10	Cooling Tower Replacement 619	2,608	9	200			9	200
Oct-10	Steam Trap Loss Recovery-Phase 2		0	0	3,166	$ 30,267	3,166	30,267
Oct-10	Metasys Sensors	860	3	66			3	66
Oct-10	Heat Exchanger Bypass	258,263	881	19,809			881	19,809
Oct-10	Filter Replacement	12,708	43	975			43	975
Oct-10	Upgrade lighting in cooling tower	46,253	158	3,548			158	3,548
Total		3,187,182	10,875	244,675	28,231	$ 244,783	39,106	507,952

Image 2-1: Building prior to Lighting Upgrade

Image 2-2: Building after Lighting Upgrade

Lighting Upgrades

Completed in September 2009, a lighting upgrade in Building 369 (see *Images 2-1* and *2-2*) improved the average overall lighting levels from 20 to 52 foot-candles and is expected to save the Laboratory 217 thousand kilowatt-hours in energy and well over $16,000 in annual operating costs.

Argonne replaced 67 mercury-vapor and 12 incandescent light fixtures with high-output T-5 fluorescent fixtures. Additionally, daily operating time for fixtures was reduced from 24 hours to 12 hours on week days and zero hours on the weekends by means of a timer. A "Holiday Override" switch was installed to keep the lighting off during the December holiday shutdown.

Overall project cost (including construction and material costs) is roughly $58,800; the payback period for the project is estimated to be about three and a half years.

2.1.1.2 Planned Actions

The major planned energy intensity reduction project is a new CHP plant. Preliminary design is complete and the ESPC planning and contracting process is underway.

The CHP plant will be the main source of steam for the campus, with the capability to produce 5.8 MW of electricity. The project will reduce Argonne's carbon footprint by 13 percent of Scopes 1 and 2 (over 35,000 metric tons; based on 2008 baseline), and will reduce emissions of nitrogen oxides, sulfur dioxide, and other hazardous air pollutants. The CHP (*see Image 2-3*) is also projected to provide 8.4% of the overall 30% site-wide energy reduction required for goal subject buildings.

Other planned projects include a site-wide ESPC, lighting upgrades at APS, and consolidation of data centers.

Another major energy savings opportunity identified is the retro-commissioning of five major utility consumption buildings: Buildings 200, 203, 205, 212, and 362. In September 2010, Argonne applied for this retro-commissioning through the Expert Energy Efficiency Evaluations (E4) program, and the Lab has had follow up discussions with FEMP to review the application.

Argonne plans to continue its Steam Trap Upgrade program. Most of the main outdoor traps were replaced in FY 2009 and FY 2010; however, there are hundreds of traps inside buildings, many of which are in disrepair. Other major steam system projects include a steam plant energy audit and evaluation of heat recovery systems. The Utility Systems Department also has several upgrades and efforts planned using their own mechanics and operators that should provide substantial steam savings:

Image 2-3: Architectural Rendering of Proposed CHP Plant Co-located with Current Central Steam Plant

- Replacing carbon rings in the turbines on forced-draft fans to reduce steam losses.
- Replacing steam control valves on three forced-draft fans. The turbines now rotate at about 900 rpm constantly with the fan vanes nearly completely closed. More desirable is for the turbines to rotate at about 400-500 rpm with the fan vanes 40 to 60% open.
- Improving the monitoring and control of boiler blowdown to balance scale reduction, energy savings, water savings, and water treatment chemical cost savings.
- Rehabilitating the steam turbine for the #2 Feed Water Pump.
- Replacing the pneumatic damper drives for two forced-draft fans that are experiencing excessive compressed air losses.
- Conducting vibration monitoring and laser alignment of rotating equipment to improve efficiency.

The Laboratory recently completed an energy audit of its steam plant, chilled water plants, and compressed air systems. In addition, a recent workshop with building engineers and maintenance foremen identified over 30 potential sustainability projects. Finally,

Combined Heat and Power Plant

As part of the Steam Plant Life-Cycle Extension project, FMS is designing a CHP plant consisting of a gas combustion turbine and a heat recovery steam generator (HRSG) that will produce 5.8 MW of power and 110,000 lb/hr of steam. This new CHP plant will generate the bulk of the steam needed by the Laboratory (approximately 65%), as well as being able to meet 20% of the site's electric power needs.

The CHP plant will operate 8,592 hours per year, providing a base load of steam (with one week of downtime for maintenance). The HRSG will provide additional steam, either in conjunction with waste heat from the gas combustion turbine or by firing it independently during turbine maintenance periods to enhance operating flexibility.

Advantages provided by the CHP are expected to include the following:

- Increased fuel conversion efficiency
- Lower utility costs
- Lower greenhouse gas emissions
- Lower NO_x and SO_2 emissions
- Increased reliability

Argonne will continue the successful implementation of its Energy Savings Reinvestment Program. Based on the energy audit and workshop, Argonne selected the following projects for the FY 2011 Reinvestment Program.

Project Description	Estimated Annual Savings ($ k/yr)	Implementation Cost Estimate ($ k)	Simple Payback Period (yr)
Lake Michigan Water Savings Retrofits	$6.4	$15.0	2.3
Canal Water Savings Retrofits	$5.0	$15.0	3.0
Occupancy Sensors - FY 2011	$5.9	$20.0	3.4
LED Exit Lights - FY 2011	$4.0	$30.0	7.5
Insulate High Pressure Steam Piping	$5.5	$30.0	5.5
Steam Trap Repair and Replacement	$7.8	$30.0	3.8
Compressed Air and Steam Plant Study	TBD	$14.8	TBD
Repair Bldg. 376 Condensate Return	$9.4	$100.0	10.6
High Bay Light Replacement - Bldg. 450	$9.9	$50.2	5.1
High Bay Light Replacement - Bldg. 368	$10.9	$62.4	5.7
Lighting Controls - Bldgs. 201 and 362	$40.6	$125.0	3.1
APS Lighting Install, Phase 1	$5.0	$25.0	5.0
APS Experimental Hall Upgrades	$35.0	$150.0	4.3

2.1.2 Increase Renewable Energy Consumption

The Renewable Energy Consumption goal is to achieve 7.5% of the site's annual electricity consumption from renewable sources. A double credit for the savings can be taken if the energy is produced onsite. In addition to the overall energy reduction requirement, every site should have at least one renewable energy generating system by FY 2010.

2.1.2.1 Performance Status and Planned Actions

Argonne is currently meeting the on-site renewable energy goals through purchase of RECs (more details on REC purchases are provided in Section 5.3.). The Laboratory has also met the requirement to have one renewable energy generating system on site.

Extensive work has been done to evaluate use of biomass for steam production. A series of production-scale test burns was performed in FY 2009 using wood and agricultural by-product pellets mixed with coal (Image 2-4). Although both biomass mixes posed challenges with respect to their handling, the emissions results were positive.

Due to its location in the Chicago metro area, Argonne has been unable to find an affordable, large-scale biofuel source. While continuing to track the markets, the Laboratory may look at harvesting wood on-site and processing its own wood pellets as an alternative.

Image 2-4: Agricultural Byproduct Pellets Used in Test Burns at Argonne Steam Plant

In 2008, the National Renewable Energy Laboratory (NREL) completed a renewable energy assessment of Argonne. Although biomass fuel was cited as the most promising of all renewable energy resources, wind and solar energies were also suggested as possible applications.

The southwest quadrant of the Argonne campus was identified as the area best suited for wind turbines; however, wind turbines pose challenges as they would be located near the property boundary and have long payback periods. Engineers also evaluated the feasibility of installing roof-mounted wind turbines. The Laboratory is currently meeting with vendors to forward the discussions on the feasibility of installing new high-conductance wind turbines.

Image 2-5: Renewable Energy Outdoor Lighting Fixture

The NREL assessment recommended five sites, Buildings 46, 21, 223, 440, 450, as being best suited for roof-mounted solar arrays. At the time of the assessment, these systems were extremely cost-prohibitive. The study also evaluated a ground-level photovoltaic system sized at 1.5 MW on the east side of the Argonne campus. That system also had very long payback, in excess of 75 years. With the ongoing advances in technology and materials, however, Argonne is reassessing the feasibility of solar and wind systems, especially to offset planned growth in high performance computing. Due to its leadership in energy storage systems, Argonne is well-positioned to couple intermittent renewable energy generation - such as solar and wind - with technology that can store the energy to meet load demands.

This past year, the Laboratory installed outdoor lighting fixtures powered by renewable energy (see *Image 2-5*). The lights are LED-type elements, powered from a combination of a solar panel and wind turbine. A power supply feeder is not needed for the new lighting poles.

A DOE/U.S. Army research program at the Laboratory is providing three hydrogen fuel cells to provide back-up power. The units will be installed at an APS Experiment Hall (15 kW), Building 436 Laboratory Office Module (LOM) (10 kW), and Building 129 (5 kW). DOE has also funded a

study for a 400 kW fuel cell at the CNM powered by natural gas. Although not renewable, the fuel cells produce considerably less greenhouse gas when compared to conventional fossil-fueled power systems.

2.1.3 Reduce Departmental Fleet Petroleum Used by 2% Annually and Increase Alternative Fuel by 10% Annually

The EO requires the Laboratory to reduce fleet petroleum usage by 2% annually for carbon fuels and increase the alternative fuel usage by 10% annually from a 2005 baseline.

2.1.3.1 Performance Status

Figures 2-4 and 2-5 show the breakdown of fuel use and associated emissions. Argonne has met and exceeded all goals related to fleet transportation. A 2009 internal review found the agency-owned fleet vehicles at Argonne had an average age of 17 years, with a total annual repair cost of over $200,000. Since that time, Argonne has completely replaced its fleet with one that is entirely GSA-leased. The fleet manager has also introduced smaller and more fuel-efficient vehicles, including:

- 16 new compact and subcompact sedans
- Five hybrid electric vehicles
- Five 100% electric “Neighborhood” vehicles. Two dedicated charging stations were also installed to enhance the convenience of charging these vehicles. The stations have electricity-use tracking capabilities through the site-wide METASYS™ system.

These actions have contributed to an 80% petroleum reduction in fuel use and a 75% alternative-fuel increase, greatly exceeding EO goals (see *Figure 2-5*).

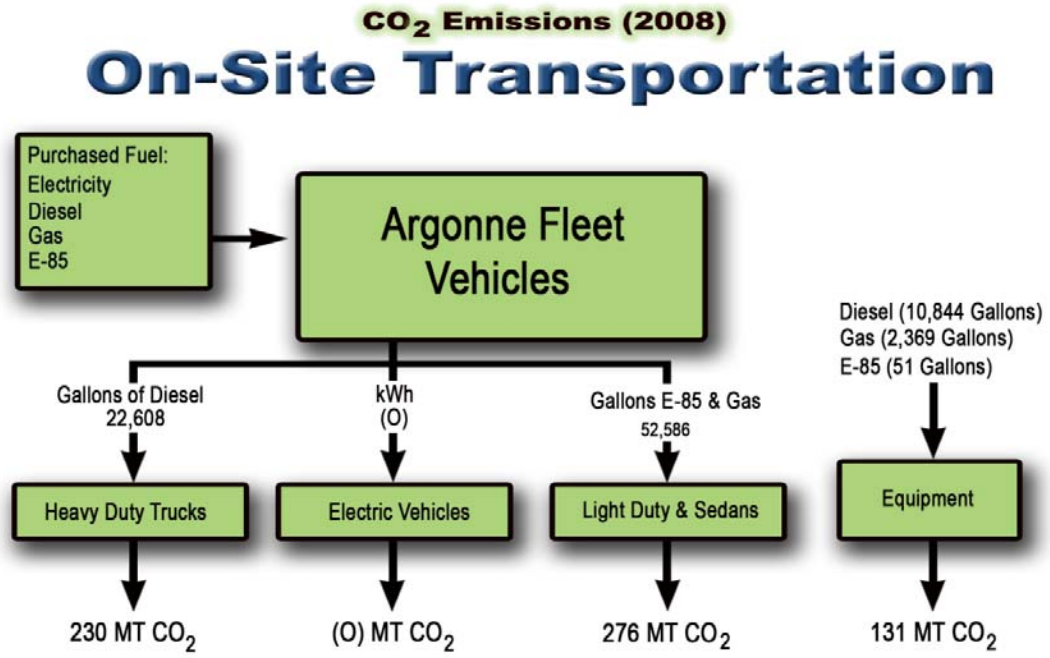


Figure 2-4: On-site Transportation Emissions

2.1.3.2 Planned Actions

Planned actions for continued progress include:

- Increase the use of hybrid electric vehicles as they become available through the GSA lease.
- Develop and implement a plan for installing electric charging stations throughout the Laboratory for neighborhood electric vehicle use. Argonne is working with Commonwealth Edison in an effort to take part in a pilot program for on-site electric vehicles and solar-powered charging stations.
- Evaluate the use of bio-diesel mixes in 2011.
- Evaluate the expansion of preferred parking for energy-efficient and/or electric vehicles.

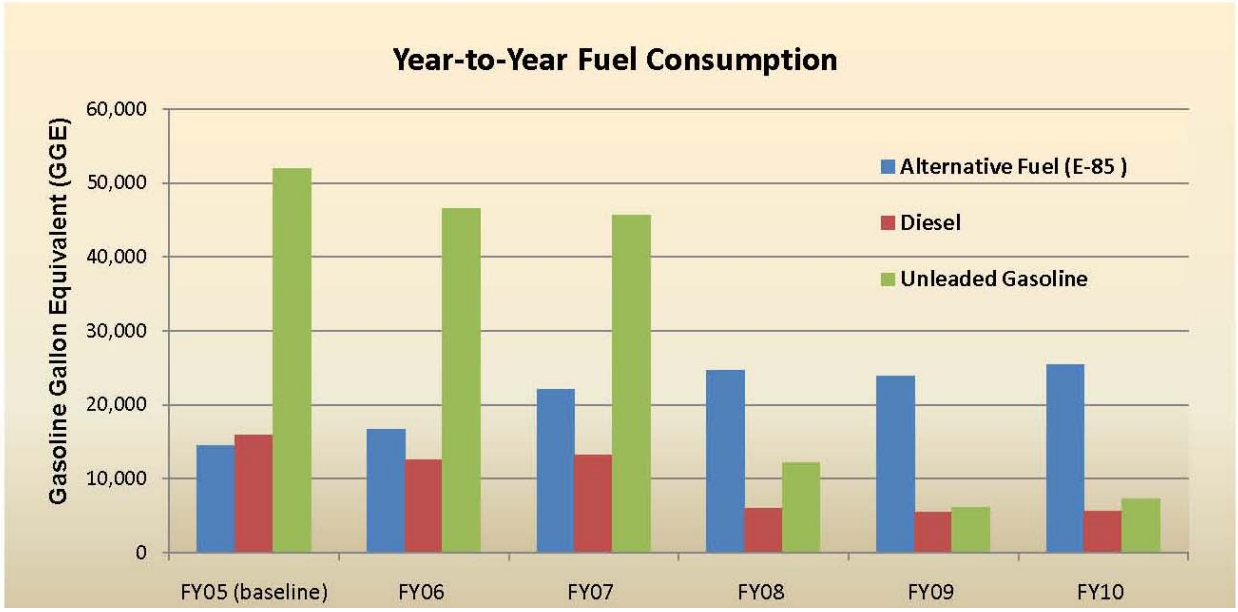


Figure 2-5: FY 2005 to FY 2010 Fuel Consumption

2.1.4 Metering

EO 13514 requires advanced metering for electricity by 2012 and advanced metering for steam and natural gas by 2016 to the maximum extent practicable. Standard billing level metering is required for water.

2.1.4.1 Performance Status

Plant engineers recently surveyed all existing electric meters and metering systems during FY 2010. The survey showed a number of advanced meters have been installed on more recent construction and renovation sites. However, with the exception of one building, the advanced meters are not tied into an information system that provides real-time reporting and display of the data. The data from this survey was used to generate a proposal for development of an energy information system to collect, trend, and report both the advanced and standard electric meter data throughout the campus.

In FY 2010, Argonne completed integration of the site-wide building automation system (i.e., Johnson Controls Metasys® system) with the metering and monitoring of mechanical and electrical systems in Building 214. The work included lighting, dimming, occupancy sensors, and daylight harvesting for eight offices. The Metasys® system allows real-time and historic building utilities usage to be displayed on a computer monitor in various formats, such as Excel spreadsheets, a 3-D chart, or a trending graph.

There are 38 natural gas meters employed at various building locations and at the central steam plant. Domestic, laboratory, and canal water are currently metered using 145 meters; 97 of which have remote-reading capability. Steam consumption is monitored by 34 remote-reading meters. None of the steam, water, or natural gas meters are advanced.

2.1.4.2 Planned Actions

As detailed above, Argonne plans to develop a campus wide Energy Information System. Argonne's FMS Division and Computing and Information Systems (CIS) Division, along with Argonne Building Technologies Program researchers, have teamed to develop specifications for collecting, viewing and analyzing the data. This team is meeting with vendors and conducting site visits to help select the best product and integration team.

2.1.5 Cool/White Roofs

Effective June 1, 2010, DOE required roof replacements and roofs for new construction to be cool roofs and have a thermal resistance of at least R-30.

2.1.5.1 Performance Status

Since 2004, all new roofs and replacements have been cool roofs. Argonne has over 2.4 million sq ft of roofing with approximately 275,000 sq ft (11.5%) being cool roofs.

2.1.5.2 Planned Actions

The Roof Replacement program will continue to replace about 35,000 sq ft of existing roofing systems annually. New buildings, of course, are being designed with cool or green roofs. With the roof replacements and Argonne's planned demolition and modernization program, the Laboratory expects to have over 22% cool roofs by 2015.

2.1.6 Training

DOE Order 430.2B requires training for energy and water management personnel, employee incentive program, and outreach programs. Additionally the Strategic Sustainability Performance Plan (SSPP) commits DOE to have each site energy manager attain Certified Energy Manager (CEM) qualification and to include energy conservation and recycling in employee orientation programs.

2.1.6.1 Performance Status

Argonne has taken a number of steps to improve the knowledge and expertise of its workforce with regard to sustainability. Core team sustainability training has included:

- "Lunch and Learn" seminars on energy and water savings technologies and products, including vendors and topics:
  - Rockwell Automation – energy controls and meters
  - Grainger – water savings and air filtration

  - 3M – window films
  - Labconoco – energy-efficient fume hood installations

- FEMP Thursday afternoon webinars
- Representation at GovEnergy, ComEd Energy Efficiency, Midwest Waste Heat Recovery Workshop, Labs 21, Green Building, and other major federal and local conferences
- Attending five-day Energy Manager training sponsored by the Association of Energy Engineers. Argonne now has four Certified Energy Managers and one LEED AP architect on staff.

For general workforce awareness Argonne has:

- Published an annual Energy/Sustainability report
- Published numerous articles in the *Argonne Today, Argonne Now,* and the Argonne website
- Created a P2 course that all employees have completed
- Developed EMS and ISO 14001 courses that over 450 managers and environmental compliance representatives have completed
- Completed a draft communications strategy on its Sustainability Program

2.1.6.2 Planned Actions

Full employee and management commitment is necessary to achieve Argonne's sustainability goals and vision. A sustainability website and two contests are scheduled to start up in 2011 to develop awareness and encourage involvement. The first contest will be designed around green transportation through employee commuting and employee business travel. The second contest will be a competition between buildings to reduce electrical energy. Argonne is currently having discussions with a vendor that provides safe and affordable plug meters that can be given to employees to monitor their power consumption both at work and at home. Incorporation of this type of tool would provide great impact and awareness of how employees can cut their power demand at work and save on their home electricity bills. Development of the Energy Information System and display of power and sustainability data will also greatly enhance energy awareness.

As detailed in Sections 2.10 and 4.0, the Laboratory has also set up a Strategic Transformation Team to get researchers involved in identifying sustainability solutions. The planned website includes a feature to also gather sustainability ideas from all employees.

Argonne's Sustainability Communications Plan also outlines training, posters, talks, and awards designed to educate employees and get their commitment.

2.1.7 SF_6 Reduction

Sulfur hexafluoride (SF_6) is a nontoxic, nonflammable gas that is used in electrical systems (due to its high dielectric strength) to prevent arcing. Along with circuit breakers and switchgear in electrical transmission systems, SF_6 is employed at Argonne in such scientific applications as accelerators, Van de Graaff generators and high voltage electron microscopes. Argonne also emits a small amount of GHGs from purchased refrigerants (see *Figure 2-6*).

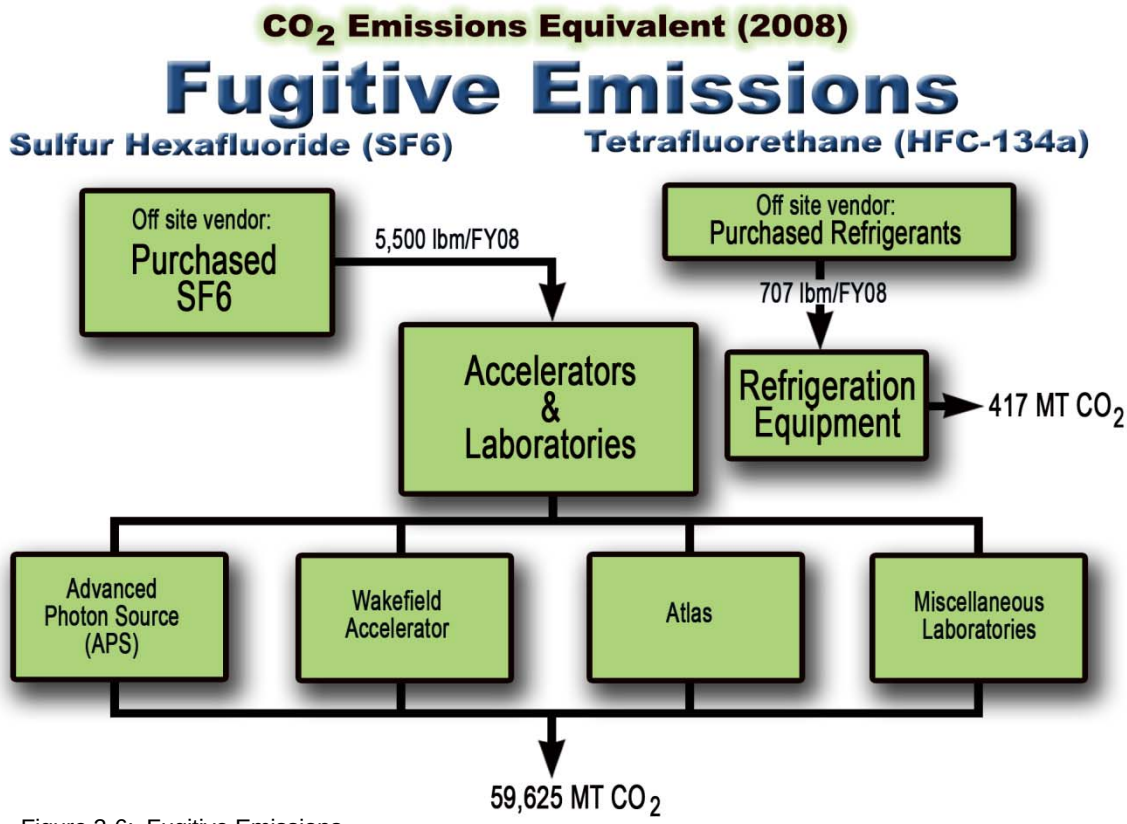


Figure 2-6: Fugitive Emissions

The global warming potential of SF_6 is significant, with one pound of SF_6 equivalent to 23,900 lb of carbon dioxide (CO_2). Emissions of SF_6 occur from two activities: losses through equipment leaks, and emissions when equipment needs to be opened for servicing and maintenance. While SF_6 is relatively inert, exposure to very high voltage environments can result in the creation of corrosive by products, which could require replacement of the gas. The SSPP commits DOE to acquire SF_6 capture and storage equipment, develop training, and deploy capture programs at key DOE sites.

2.1.7.1 Performance Status

In FY 2010, an SF_6 users group was formed to evaluate ways to reduce emissions of the gas from operating equipment. Evaluations of programmatic equipment were conducted by a consultant to develop leak detection and repair procedures. Prior to this analysis, operating losses of SF_6 due to leaks were not considered significant because SF_6 was not regulated and the cost to replace lost gas was relatively low. The impact of SF_6 on the Argonne greenhouse gas emission inventory and increasing costs for replacement gas provided an impetus to reduce losses from equipment leaks. While some SF_6 facilities do possess a recovery system for transferring the gas when equipment maintenance is required, there are other systems where the only recourse is venting to the atmosphere. A gas recovery vendor has toured several SF_6 facilities in the last few weeks to evaluate the feasibility of establishing a program of recovering SF_6 for reclamation. Results of these initial actions have been significant, with FY 2010 fugitive emissions at only 27% of FY 2008 baseline levels.

2.1.7.2 Planned Actions

Planned actions include continued development of leak detection and repair procedures. The purchase of more sophisticated detection equipment will be evaluated. There will be continuing interaction with interested vendors for development of an SF_6 recovery/reclamation program. SF_6

recovery equipment is already scheduled to be purchased for the Wakefield Particle Accelerator, and specifications are presently being prepared for a similar system at the APS. With an improved leak detection, repair, and recovery program and equipment, Argonne hopes to achieves at least a 90% reduction in SF_6 emissions within one to two years.

2.1.8 Overall Reduction of Scope 1 and 2 GHG Emissions

The DOE goal for Scope 1 and Scope 2 Greenhouse Gas Emissions reductions is 28% by FY 2020 (from the FY 2008 baseline).

2.1.8.1 Performance Status

Table 2-3 shows Argonne's official FY 2008 Scope 1 and 2 GHG baseline and FY 2010 emissions.

Table 2-3: 2008 Scope 1 and Scope 2 GHG Baseline

Input	FY 2008 Consumption	FY 2008 MT CO_2e	FY 2010 MT CO_2e
Coal	10,254 tons	22,938	15,525
Natural Gas	662,612 MCF	36,321	43,231
Gasoline	68,350 gal	608	179
Diesel	34,376 gal	366	389
E-85 Ethanol/Gas	39,350 gal	46	47
F-Gases(SF_6, HFC-134A, PFC)	6,207 lb	60,041	16,278
Electricity	265,944 MWh	186,488	196,302
Landfill Gas and Wastewater Treatment	N/A	2,275	2,104
	Total	309,074	274,065

As shown in the table and in Figure 2-7, Argonne has achieved an 11.3% reduction in Scope 1 and 2 GHG emissions. This was achieved mainly through a dramatic reduction in SF_6 fugitive emissions. Emissions from the steam plant remained relatively constant, whereas emissions associated with purchased power actually increased due to start up of new facilities and laboratories. Overall, however, the large fugitive emissions reduction more than compensated for the purchased power increase.

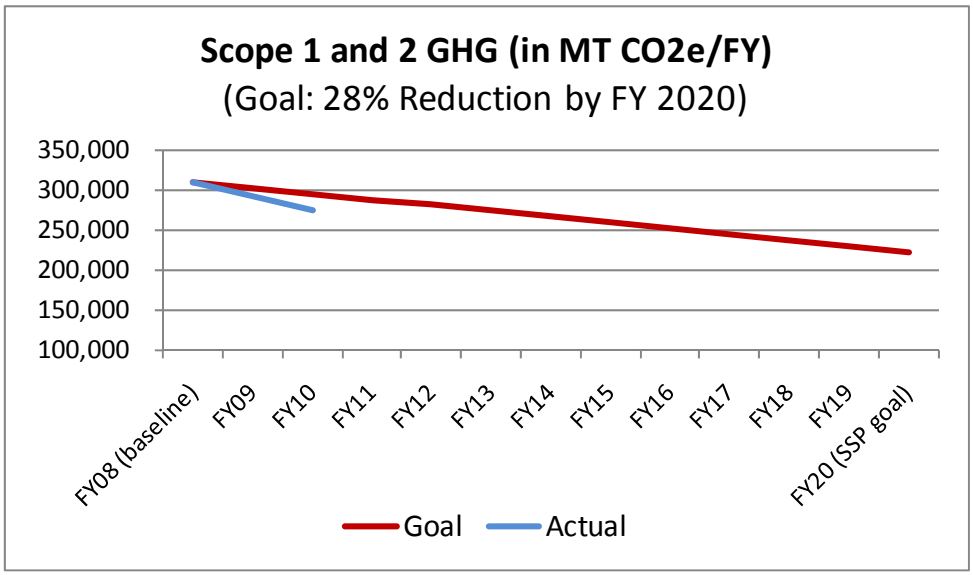


Figure 2-7: Scope 1 and 2 GHG SSP Goal

2.1.8.2 Planned Actions

As indicated in Section 1, Argonne has developed a multi-faceted action plan that includes Scope 1 and 2 components in electricity, fuel combustion, and fugitive emissions. Sections 1.1 through 1.7 of this document provide details on the plan. With full implementation, Argonne expects to exceed the 28% DOE target for Scope 1 and 2 greenhouse gas emissions and achieve a 40% reduction. *Table 2-4* shows Scope 1 and Scope 2 reduction targets.

Table 2-4: Scope 1 and 2 Reduction Targets

Focus Area	Scope 1 FY08 Emissions (MT CO_2)	SSP Reductions (MT CO_2)	Reduction (percent)
Transportation (Scope 1)	1,011	195	19
Steam Production	59,259	36,300	66
Electric Intensity	186,488	20,450	13
Fugitive Emissions (F-gases, Landfill, and Wastewater)	62,317	54,036	87
Renewable and Clean Energy	0	13,987 (credit)	N/A
Total	309,075	124,968	40.4%

2.2 Scope 3 Greenhouse Gas Emissions Reductions

The major areas for Scope 3 emissions are employee commuting, business ground and air travel, transmission and distribution (T&D) losses, off-site wastewater treatment, and off-site waste disposal. DOE is committed to reducing its Scope 3 emissions 13% by FY 2020. *Table 2-5* is Argonne's FY 2008 Scope 3 inventory and latest FY 2010 emissions figures.

Table 2-5: 2008 Scope 3 Inventory Baseline

Category	FY08 Amount	FY08 MT CO_2	FY10 MT CO_2
T&D Losses (MWh)	16,435	11,521	12,131
Business air travel (miles)	23,863,555	6,535	6,179
Business ground travel (miles)	1,365,743	512	399
+Employee commute (miles)	~34 million	11,386	11,754
	Total	**29,954**	**30,463**

2.2.1 Performance Status

Table 2-6 and *Figure 2-8* show Argonne's Scope 3 emissions have risen slightly (by 1.7%) since 2008. The T&D losses went up due to new facilites coming on-line and a slight increase in site occupant population (increasing the employee commute component). Business travel emissions did decrease slightly due to changes in trip distances.

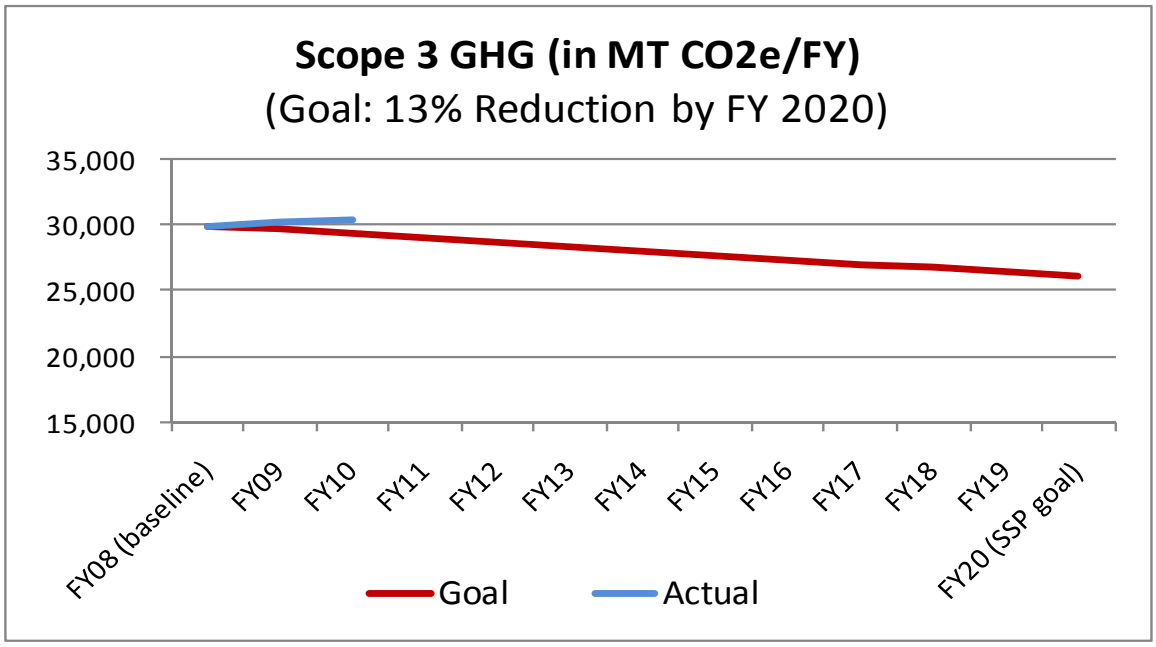


Figure 2-8 Scope 3 GHG Goal and Progress

2.2.2 Planned Actions

The three largest contributors to Scope 3 emissions are employee business air travel, employee commuting, and electrical T&D losses.

Total employee air miles traveled average around 25 million miles per year. Reduction efforts would include evaluation of future air travel to determine the necessity of trips needed for mission accomplishment. Argonne will evaluate the possibility of shifting to alternative transportation modes (rail, bus) over short range (<300 miles) air travel. Also, consideration will be given to increased use of web-based meetings and teleconferencing to reduce the frequency of business air travel.

Another possibility for reduction in GHG emissions from air travel is offsetting of emissions by commitment to reforestation. American Forests and Global ReLeaf are currently partnered with a number of major corporations to help offset air-travel-related emissions.

Promotions and incentives to increase carpooling, preferred parking for hybrid cars and use of other low emission vehicles will be included in efforts to reduce employee commuting. The evaluation of existing public transportation systems is also scheduled to determine options the Laboratory could provide to support or supplement the limited public transportation available to employees. Compressed work schedules (e.g., four 10-hour days) and telecommuting may also be considered for reduction in employee commuting emissions.

Due to plans to drop purchased power use in the short term through the CH&P plant, reduced T&D losses will significantly help drive Scope 3 emission reductions. However, as power demand increases with construction of new HEMSF, this number may begin increasing, so that additional offsets from the transportation area may be required.

Table 2-6 provides a summary of initial reduction targets.

Table 2-6: Major Strategic Initiative Summary: Scope 3 Emissions

Focus Area	FY 2008 Emissions (MT CO_2)	SSP Reductions (MT CO_2)	Overall GHG Reduction (percent)
T&D losses	11,251	4,482	40
Business air travel	6,535	654	10
Business ground travel	512	51	10
Employee commute	11,386	1,708	15
Total	**29,954**	**6,895**	**23**

2.2.3 Behavior Change

This section provides a brief summary of behavior change methodologies discussed throughout Argonne's SSP. It is first necessary to provide education and awareness to employees. This will be done through training, briefings, information kiosks/displays, our sustainability webpage, and development of an energy and greenhouse gas information system. The information presented will describe the challenges faced, progress to date, and how all employees can positively contribute. Examples of how employees can help will be regularly provided (e.g., green

purchasing reminders; recycling reminders, eliminating office refrigerators and microwaves, eliminating space heaters, turning off lights, lowering thermostats, shutting down computers, etc.)

Sustainable behavior and participation will be encouraged through two contests. The first will be an intra-building competition based on energy reduction. Initially the contest will be set up based on monthly electric meter data; however, as Argonne's Energy and Sustainability Information system matures; the data will be served up in real time via the website and in-building computer monitors.

The second competition will be between major organizational units and will focus on reducing GHG from employee commuting and employee business travel through use of car pooling, biking, high efficiency vehicles, videoconferencing, and other green transportation activities. The contest may eventually expand beyond "green" travel into accounting and crediting of other sustainable behaviors, including those done outside of work.

The Lab also plans to continue its participation in the American Cancer Society's annual Active for Life Program – a contest for healthy living that provides point rewards for walking, biking and other activities.

To also encourage and promote sustainability, the Laboratory is considering awards programs for ideas and for excellence in sustainable behavior.

2.3 Comprehensive Greenhouse Gas Inventory

Table 2-7 gives a breakdown of Argonne's overall GHG baseline inventory and reduction targets.

Table 2-7: Major Strategic Initiative Summary

Focus Area	FY 2008 Emissions (MT CO_2)	SSP Reductions (MT CO_2)	Overall GHG Target Reduction (percent)
Transportation (Scope 1 and 3)	19,445	2,578	13.3
Steam Production (Gas and Coal)	59,259	36,300	61.2
Electricity (Scope 1 and 3)	198,009	20,450	10.3
Fugitive Emissions (F-Gases, Landfill, and Wastewater)	62,317	54,036	86.7
Renewable and Clean Energy	0	13,987 (credit)	7.5
Total	**339,030**	**127,350**	**37.5**

The Laboratory is outlining an aggressive GHG reduction program; however, Argonne's actual and planned growth since the 2008 GHG baseline exacerbates the challenge of meeting EO goals. Four major new facilities — the Theory and Computing Sciences (TCS) Building, the Ricketts Laboratory, the Argonne Leadership Computing Facility (ALCF), and the Sub-Angstrom Microscopy and Microanalysis (SAMM) Facility — have come on-line since FY 2008.

Adding to the growth are near-term startups of the new Central Chilled Water plant, ESB, Advanced Protein Crystallization Facility, and MDL. The upgrade to the APS may also result in an incremental demand increase.

To balance this growth, Argonne is aggressively working to demolish legacy facilities that, although unused, still require some heat and power for safety and security reasons. Buildings 301 and 330, at a total of 82,759 sq ft, have been recently demolished. Building 310 (41,434 sq ft) is scheduled for demolition in FY 2011. Argonne is also de-inventorying several nuclear facilities in preparation for deactivation and demolition. Critical to the success of Argonne's sustainability plan, is the Laboratory's ability to obtain continued support from Environmental Management (EM) to decontaminate and decommission legacy facilities. In the interim, Argonne is evaluating how operations can be consolidated through footprint reduction, such that entire buildings and/or wings can be put in caretaker status. Though this would lower energy consumption considerably, the Chicago area climate requires heating of the building to prevent freezing of water-based fire protection systems.

Approximately 60% of Argonne's greenhouse gas emissions result from purchased electricity. The current Environmental Protection Agency (EPA) e-Grid emission factor for Argonne's region is 0.701 tons of CO_2e/MWh purchased. However, the local disclosure from Commonwealth Edison based on the actual utility plant make up in their distribution region is 0.34 tons of CO_2/MWh. Unfortunately, current policy requires use of the e-Grid factors. Argonne will continue to explore methods of crediting purchase of clean power that is produced off-site, through mechanisms such as purchased power agreements. With predicted growth, especially in the area of HEMSF, the accounting of GHG from local utilities will be critical for Argonne's and DOE's success in meeting GHG goals. More details on growth projections and offsets through renewable energy strategies is provide in Section 5.0.

2.4 High-Performance Sustainable Design

Argonne is working toward a minimum of 15% of new and existing buildings (over 5,000 sq ft) meeting or exceeding High Performance Sustainable Building (HPSB) Guiding Principles or LEED certification by 2015. Two buildings currently meet this criterion. Based on an expected growth to 77 buildings by FY 2015, 10 additional "green" buildings will be required to meet the 15% goal. *Table 2-8* shows buildings that Argonne expects to meet the criteria and contribute towards the 15% goal.

Table 2-8: Green Buildings Strategies

Action	Plan	Status	Fiscal Year	Building Count
Existing Buildings				
Transportation Building	LEED Certified	Currently meets criteria	2010	1
SAMM	LEED Gold	Currently meets criteria	2011	1
Lab Office Modules	HPSB	FY 2011 feasibility study completion	2014	2 - 6
Center for Nanoscale Materials	LEED Silver	Application submitted and accepted	2011	1
New Construction (>$5 mil)				
Energy Sciences Building	LEED Gold	Design underway; LEED assessment complete and on target	2013	1
Materials Design Laboratory	LEED Gold	Preliminary design completed	2015	1
Advanced Protein Crystallization Facility	LEED Gold	Conceptual planning underway	2014	1
APS – Early Assembly Building	LEED Gold	Conceptual planning underway	2015	1
APS – Long Beamline	LEED Gold	Conceptual planning underway	2015	1
New Construction (<$5 mil)				
Central Chilled Water Plant	HPSB / LEED	Construction underway	2011	1
Combined Heat & Power Plant	LEED Silver	Preliminary design meets criteria	2013	1
		Total		12 -16 (15 to 20%)

2.4.1 HPSB New Construction

2.4.1.1 Performance Status

Preliminary design for the ESB (Image 2-6) was completed in FY 2010. The design firm recently completed the LEED assessment. The facility is being designed to achieve LEED points, exceeding LEED Gold status.

2.4.1.2 Planned Actions

Argonne has several projects in the new construction development phase planned to meet EO requirements:

- Energy Sciences Building
- Materials Design Laboratory
- Advanced Protein Crystallization Facility
- Combined Heat and Power Plant
- Chilled Water Plant (200 Area)

SAMM Facility Wins Two Energy Awards

Argonne National Laboratory's Sub-Angstrom Microscopy and Microanalysis facility (SAMM) received a Federal Energy and Water Management Award and a Department of Energy Management Award. These awards recognized Argonne's efforts in designing a facility that was both scientifically cutting-edge and environmentally friendly. The SAMM building is expected to save approximately 1 billion Btu, $24,100 in energy costs, and 5,700 gallons of water per year.

Image 2-6: Energy Sciences Building

Energy Sciences Building's Integrated Sustainable Design

Sustainable building practices are an integral component of environmental stewardship and when successful, make a positive contribution to the earth by minimizing a building's impact on the global, regional, and local environment.

Argonne's Facilities Management and Services Division is leading the Energy Sciences Building's Integrated Design Team efforts that includes DOE, building users, Argonne subject matter experts, and an architect. The Integrated Design Team's efforts started at the beginning of the project and will continue throughout the project's life, assuring good design and sustainable practices.

2.4.2 HPSB Existing Buildings

Argonne is using the EPA Portfolio Manager to assess existing buildings as candidates for system modifications. Facilities that have the greatest potential and are economically feasible will be included in the HPSB existing building program. Argonne anticipates that only two existing buildings will need to be upgraded to meet the 15% HPSB goal by 2015.

2.4.2.1 Performance Status

Argonne has built and is operating the following existing LEED buildings, which qualify for HPSB status:

- Building 46 – Shipping & Receiving
- Building 216 – Sub-Angstrom Microscopy and Microanalysis Laboratory (SAMM)
- Building 440 – Center for Nanoscale Materials

In FY 2010, Argonne performed an assessment of all existing facilities to screen out those facilities that have the greatest potential to meet HPSB requirements. In parallel with the assessment, many of Argonne's policies and procedures were revised and updated to reflect the HPSB guiding principles. Twenty guiding principle policies were completed.

2.4.2.2 Planned Actions

The most promising candidates for HPSB are the Laboratory Office Modules (or LOMs) at the APS. There are eight LOMs that are categorized as separate buildings in FIMs, although they are nearly identical in construction. Depending on the cost to meet HPSB compliance, the Laboratory may choose to retrofit up to six LOMs that would exceed the 15% target for Argonne and contribute to meeting the overall DOE EO goal.

By the end of 2012, Argonne will finalize a feasibility analysis to identify the building systems and components that will require upgrades to meet the specific HPSB requirements within the LOMs. Argonne anticipates changes to the mechanical systems, water fixtures, building envelope, and electrical systems will be required. Conceptual engineering will be performed and estimates provided to prepare project plans and budgets.

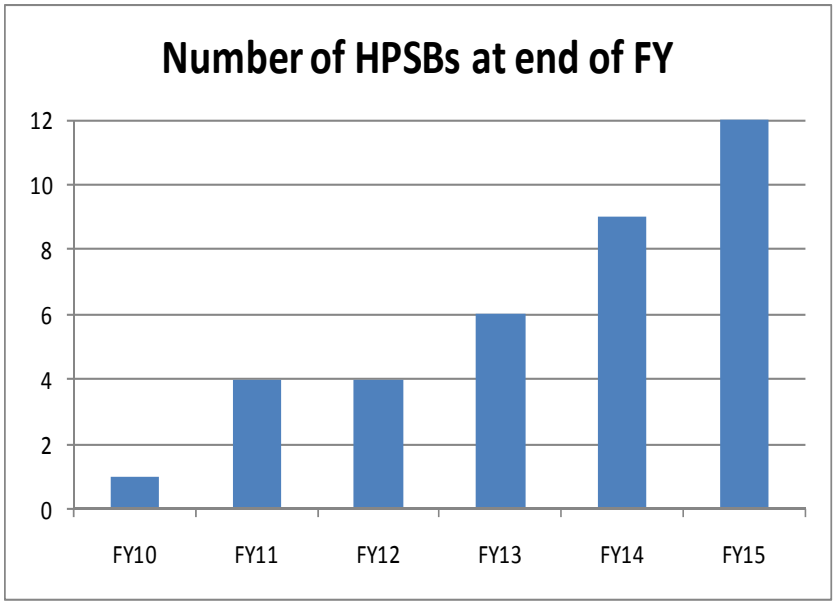


Figure 2-9: HPSB by Fiscal Year

2.5 Regional and Local Planning

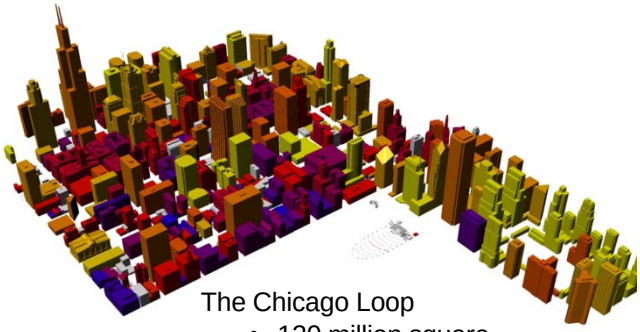
The SSPP and EO 13514 require DOE to participate in regional planning activities; align policies with local planning efforts; ensure that planning for new facilities considers interface with local developments; identify impacts of energy usage and alternative energy sources in National Environmental Protection Act (NEPA) documents; and coordinate with regional programs for ecosystem, watershed, and environmental management.

2.5.1 Performance Status

Argonne has established a number of community outreach programs to interface with the Lab's neighbors and the public in general. The main communication vehicles are: the Community Leaders Round Table, Community Update Newsletters, tours, and the Argonne Speakers Bureau. In addition to these, Argonne maintains a public website that provides information on many topics.

2.5.2 Planned Actions

Argonne plans to use the established communication vehicles to address cooperative efforts related to regional and local planning. The Community Leaders Round Table, which is composed of elected and appointed public officials, will be the primary bridge with the public and local officials in addressing the requirements of the SSPP and EO 13514. Specific regional and local individuals and organizations will be identified and cooperative relationships will be developed. Argonne long-range site development processes will play a leading role in generating information for this interface.



The Chicago Loop
- 120 million square feet built area

Image 2-7: The Chicago Loop
Image Source: Adrian Smith+Gordon Gill

Chicago Loop Model

Argonne, in collaboration with the City of Chicago and the premier architecture firm of Adrian Smith and Gordon Gill (ASGG) will retrofit the Chicago Loop. The parametric model contains 550 buildings in the Chicago Loop (*Image 2-7*). This provides a platform for impact monitoring, scenario projection, behavior change marketing, and public consensus building. By uniting the other partners, this project represents a new, multiyear project that ultimately incorporates supporting high-impact innovation, supporting speed and scale change and capturing hearts and minds. Because the database is already in development and partners are currently acting independently in many aspects, the target is to develop a plan for full capacity synergy (FY 2011) and continue (FY 2016) to reduce energy requirements by 30%.

Funding for the project provides support to the collaborative development of a multi-scale parametric model by Argonne and ASGG as a critical aspect to the decarbonization of the city. As opposed to the traditional model for energy performance contracting that addresses buildings as discrete elements and building owners independently, the parametric model allows for energy performance contracting to be expanded to a larger region encompassing multiple buildings and building owners. The advantage of this approach is that the opportunity to share multiple forms of energy between buildings and centralized infrastructure can be assessed and used to improve the value proposition for the performance enhancement of buildings within the study area.

New Clean Energy Ecosystem to Include University of Chicago and Argonne

The Clean Energy Trust has received a $1 million grant from the U.S. Department of Energy to help transfer research from the University of Chicago, Argonne National Laboratory, and other Illinois universities and science labs into clean-energy technologies and viable businesses. A new non-profit organization, the trust seeks to connect applied scientists with entrepreneurs who have the finance and business expertise to fully develop new ideas for commercial deployment.

The DOE grant will be used to initiate four separate university–based programs, including seed money, business training, awareness education, and sector–specific business development support. Founded by seven business and civic leaders, including University of Chicago, the trust seeks to leverage the area's strengths, including its major corporations, proven manufacturing capabilities, transportation infrastructure, and intellectual resources, to create a thriving, clean energy ecosystem.

Focusing on renewable energy, smart grid initiatives, and transportation, the trust will soon launch a Clean Energy Business Plan Competition, in which Illinois scientists and entrepreneurs will compete for $100,000 in seed funds and business services. It also will create the Clean Energy Boot Camp, giving entrepreneurs immersion training and a chance to develop new business networks.

2.6 Water Use Efficiency and Management

2.6.1 Water Efficiency

Argonne met the prior goal to reduce water intensity (gal/GSF) ratio 16% by the end of FY 2015, relative to FY 2007 baseline. EO 13514 extended that goal to reduce potable water 26% by 2020 and established a new category of industrial, landscaping, and agricultural (ILA) water consumption, with a 20% reduction goal by FY 2020, relative to FY 2010.

Water in use at Argonne originates from the DuPage Water Commission, which is used as domestic and lab water; and from nearby canal water, used for industrial purposes. A number of water conservation measures are completed, underway, or identified in the following two subsections.

Water Conservation Measures

- ESPC 2 (site-wide condensate return)
- Building 203 condensate return;
- Survey/elimination of steam traps losses, Phases I and II
- Buildings 314, 315, and 316: Condensate return piping for chilled water/hot water/steam distribution
- Building 377C: cooling tower modernization
- Cooling water recycling (site-wide)

2.6.1.1 Performance Status

As shown in Figure 2-10, by the end of FY 2010 Argonne had achieved 16.96% water intensity (gal/GSF), exceeding the original nine-year DOE goal in only four years.

Several of the projects completed to achieve this goal are shown in the text box above. The most significant reductions were made by recirculating the cooling water to the central chilled water

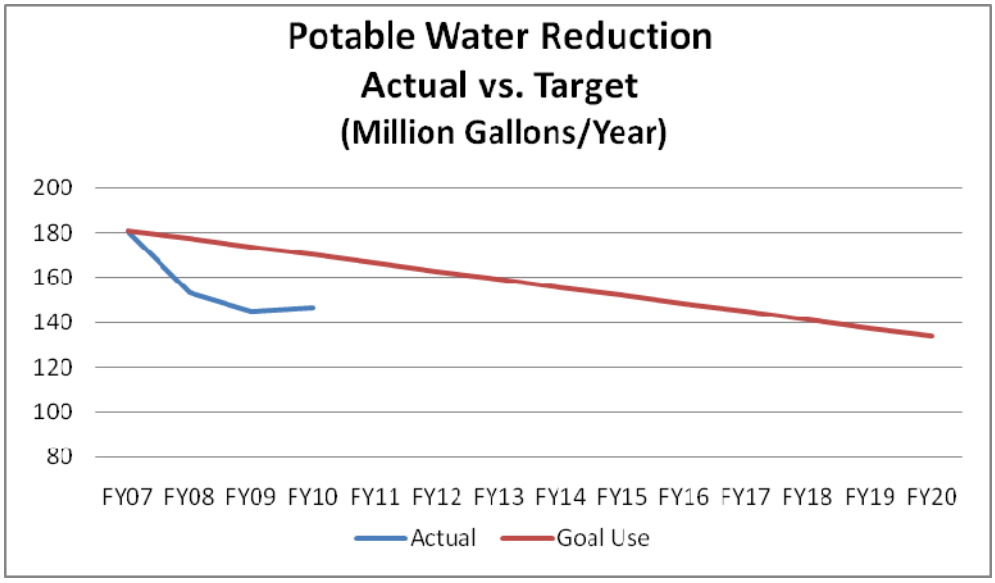


Figure 2-10: Potable Water Use

loop, instead of once-through usage. The resulting water savings were over 27 million gallons per year at a cost savings of $58,927.

Argonne's landscaping practices have been adjusted for water-use reduction. Planting schedules match seasonal precipitation patterns so new plants have time to become established without intensive watering. Drought-tolerant plants are selected. The Chicago area native prairie dropseed and bur oak reduce landscape water demands. Plants that require higher water quantity are minimized or integrated into settings with naturally occurring water.

2.6.1.2 Planned Actions

Argonne's main potable water strategy is to repair condensate and steam traps and expand our water recycling program. Retrofit to low-flow fixtures will also be accomplished on renovations and new construction. Through the recycling program alone, Argonne should greatly exceed the new 20% reduction goal for potable water.

The Laboratory's main opportunity for industrial water reduction is in the area of cooling tower blowdown. By changing chemical treatment, it may be possible to reduce blowdown cycles by over 50%. The other significant canal (industrial) water reduction opportunities are at Argonne's Central Steam Plant. These opportunities will also be evaluated over the next two years.

Other potential measures for both potable and industrial water conservation include installation of an advanced metering infrastructure and reduction of leaks in the water distribution systems.

2.6.2 Storm Water Management

2.6.2.1 Performance Status

Prior to FY 2010, Argonne voluntarily incorporated sustainable storm water management into a variety of projects across the Argonne site, ranging from rain garden construction to wetland restoration efforts and establishment of native vegetation as part of the rehabilitation of vacant parcels at the site. *Table 2-9* summarizes these efforts.

Table 2-9: Storm Water Management Practices

Project Name	Fiscal Year	Description
Center for Nanoscale Materials	2005	Rain garden construction and establishment of native plants to enhance soil quality and storm water retention capability
East Area – Buildings 4, 5, and 6 demolition	2006	Establish native plants in former building footprints to enhance soil quality and storm water infiltration capability
Building 46 expansion	2006	First LEEDs project at Argonne (Silver certification); project include establishment of native vegetation
Sub-Angstrom Microscopy and Measurement Facility	2007	Second LEEDs project (Silver certification). Storm water retention basin constructed with improved native vegetation to promote storm water infiltration.
Wetland restoration east of Building 240	2008	Wetland reconfigured to increase amount of storm water retention in wetland – promotes infiltration instead of runoff.
Building 301 demolition and site restoration	2009	Former building footprint restored using native plants in lieu of grass to improve soil quality and enhance storm water infiltration capability

Beginning in FY 2010, Argonne began using the LEEDs Gold certification process to implement EO 13514 and the federal requirements noted above. As part of this effort, Argonne began incorporating sustainable storm water practices in all new building design and building upgrades.

Examples of FY 2010 projects underway include the ESB and MDL. The design of the ESB includes a directing roof and surface runoff towards a rain garden/bioswale system, which would eventually discharge into a vegetated storm water infiltration basin. Infiltration would be achieved using an elevated overflow structure directing high water not yet absorbed to a nearby existing retention feature in lieu of direct discharge to the site storm water drainage system. Also being evaluated is the use of permeable pavers in the building parking lot instead of asphalt pavement. The parking lot is designed to discharge into the vegetated storm water retention basin. The MDL building, being constructed adjacent to the ESB, will direct runoff toward the vegetated storm water infiltration basin. Also being evaluated is the construction of a green roof on the proposed parking structure that will serve both the ESB and MDL buildings.

2.6.2.2 Planned Actions

At Argonne, sustainable (or “green”) infrastructure methods will continue to be incorporated into new building design and will be employed, when possible, in retrofitting of existing buildings. Green infrastructure methods include establishment of rain gardens and bioswales, which are vegetated storm water collection and conveyance features that promote downward infiltration and evapotranspiration of storm water in lieu of conveyance of storm water to off-site waterways. Other green infrastructure storm water management methods include use of permeable pavement for traffic areas and dispersal of roof runoff to open areas or engineered storm water infiltration features. A typical example is the 200 Area Substation project scheduled to begin construction in FY 2011

Future Argonne construction planning will also implement sustainable storm water practices as part of LEED Gold certification and EISA Section 438 compliance. While specific design details are not yet available, sustainable storm water features will likely include some combination of storm water infiltration features similar to those discussed above. Additionally, these installations will be designed so that their performance will be measurable and constantly improved.

Phytotechnologies use living plants to address environmental problems. The Argonne phytotechnologies research team has successfully assisted Argonne in deploying a 4-acre on-site phytoremediation field installation, and they are expanding their research focus to address storm water management issues such as non-point pollution from runoff and subsurface flow which will be used in future storm water management projects. To gain maximum and transferrable benefits from these installations, measurable benefits will be determined such as soil water capacity improvements, plant water use, and overall measure of effectiveness (e.g., measuring amount of reduced discharge and water infiltration).

2.7 Pollution Prevention (P2)

Argonne will recommend the establishment of the following goals for management approval, consistent with DOE P2 Goals:

- Increase source reduction of pollutants and waste (conduct PPOAs);
- Divert at least 50% of non-hazardous solid waste by FY 2015, excluding construction and demolition (C&D) debris;
- Divert at least 50% of C&D materials and debris by FY 2015;
- Reduce printing paper use;
- Increase use of uncoated printing and writing paper containing at least 30% postconsumer fiber;
- Reduce and minimize the acquisition, use, and disposal of hazardous chemicals and materials;
- Evaluate the diversion of compostable and organic materials from the waste stream;
- Implement integrated pest management and landscape management practices to reduce and eliminate the use of toxic and hazardous chemicals and materials; and
- Decrease departmental use of chemicals to assist in achieving FY 2020 GHG reduction targets (see Section II - 1 and 2 above);

2.7.1 Performance Status

Argonne has had great success in conducting PPOAs; see *Table 2-10* below for all goal performance status.

2.7.2 Planned Actions

Argonne will continue to nominate projects for DOE's Environmental Sustainability (*E-S*tar) award programs to recognize and incentivize teams and individual programs that successfully reduce the generation of pollutants and wastes and effectively divert from disposal those that can be recycled or reused. *Table 2-10* includes details on planned actions.

Table 2-10: P2 Goals, Status, and Activities

Goals	Status	Activities
Increase source reduction of pollutants and waste	Exceeded performance targets each of the last four years. Argonne will continue to conduct PPOAs to identify opportunities for operational process, product, or behavioral changes.	Continue to conduct PPOAs within the Argonne P2 program and within programs; four planned in FY 2011.
Divert non-hazardous solid waste and non-hazardous, non-radioactively contaminated C&D materials and debris	Data on sanitary waste, including construction, composting, and recycling will be analyzed to assess the current performance relative to the goal and data reporting into PPTRS. Recycling contracts are in place for many waste streams (i.e., electronics, scrap metals, plastic, glass, engine oil and antifreeze, and mixed office paper).	*Activities underway*: Measuring sanitary waste and recycling volumes. *Activities planned*: o Evaluate existing pollution prevention data reported to PPTRS and establish metrics. o Meet with Procurement and Facilities Management and Services to develop a plan and contract language to meet goals. o Meet with solid waste disposal facility contract representative to discuss: ➢ Options for tracking solid waste and construction and demolition debris waste streams. ➢ Options for diverting construction and demolition debris. o Establish a pilot project for conducting zero-waste events (e.g., conferences, workshops, or social gatherings like staff picnics) to improve awareness and reduce landfill waste. o Establish a plan for increasing the placement of blue bag receptacles around the site (e.g., conference rooms). o ESQ will work with FMS to assess barriers to and resources necessary for establishing a composting program (FY 2012) o Assess reporting of recycling activities from contractors. o Conduct survey of janitorial staff to assess contents of sanitary waste.
Develop sustainable pollution prevention practices to reduce use of toxic, hazardous, and GHG-emissions contributing chemicals	Actions to improve chemical management activities have been underway for years (i.e., accurate inventory management, the ability to identify and redistribute excess chemicals, and using a system to allow for use of unused chemicals).	*Activities underway:* Chemical Management System facilitates re-use of chemicals available for use elsewhere in the Laboratory. *Activities planned:* o Evaluate EPCRA reports, Chemical Management System (CMS) and ozone depleting substances (ODS) and GHG inventories to identify chemicals of concern and potential pollution prevention opportunities.

2.8 Sustainable Acquisition

DOE's Strategic Sustainability Performance Plan commits to the following sustainable acquisition goals:

- Ensure that 95% of new contract actions, including task and delivery orders under new contracts and existing contracts, require the supply and use of products and services that are energy efficient (*E-Star* or FEMP-designated), water efficient, bio-based, environmentally preferable, non-ozone-depleting, recycled-content-containing, or are non-toxic or less toxic alternatives.

- Update departmental affirmative procurement plans (also known as green purchasing plans or environmentally preferable purchasing plans), policies, and programs to ensure that all federally-mandated designated products and services are included in all relevant acquisitions.

2.8.1 Performance Status

Procurement statistics regarding the procurement of recycled-content products (per the EPA designated list) are tracked annually.

The Laboratory's standard terms and conditions contain the following requirements in the Warranty for Supplies clause. This clause is included in all subcontract actions for the purchase of goods or services (excluding construction or A&E subcontracts):

REQUIREMENTS FOR EPA DESIGNATED ITEMS

WARRANTY OF SUPPLIES (AUGUST 2007)
The contractor warrants that the items delivered hereunder are merchantable and fit for use for the particular purpose described in this contract.

Energy Consuming Products
When the contract requires the specification or delivery of energy consuming products for use in Federal facility, the contractor will specify or deliver EnergyStar ® qualified products or products conforming to the Federal Energy Management Program's (FEMP) Energy Efficiency Requirements, whichever may be applicable, provided products with such a designation are available and are life cycle cost effective and meet applicable performance standards. Information about these products is available for EnergyStar ® at: http://www.energystar.gov/products and FEMP at http://www.eere.energy.gov/femp/procurement/eep_requirements.cfm.

Environmentally Preferable Purchasing for Desktop or Laptop Computers or Monitors
IEEE 1680 Standard for the Environmental Assessment of Personal Computer Products (Dec 2007)

(a) Under this contract, *the Contractor shall deliver, furnish for Government use, or furnish for contractor use at a Government-owned facility, only personal computer products that at the time of submission of proposals were EPEAT Bronze registered or higher. Bronze is the first level discussed in clause 1.4 of the IEEE 1680 Standard for the Environmental Assessment of Personal Computer Products.*
(b) For information about the standard, see http://www.epeat.net.

"Products provided must comply with Executive Order 13423 of January 24, 2007 Strengthening Federal Environmental, Energy, and Transportation Management."

Current Affirmative Procurement Policy:

AFFIRMATIVE PROCUREMENT

Affirmative Procurement consists of waste prevention through the purchase of products containing recovered materials. This program enhances the Laboratory's commitment to environmental quality by becoming a model consumer of environmentally preferable products.

On September 14, 1998, Executive Order E.O. 13101 was formally enacted, superseding E.O. 12873. E.O.13101 establishes more stringent guidelines for the acquisition of recycled-content products by federal agencies and contractors, and it specifically requires the Laboratory to purchase products that comply with the Environmental Protection Agency's (EPA's) recycled-content requirements. The EPA's Comprehensive Procurement Guidelines establish a list of recycled-content products that are to be purchased by federal agencies (EPA-Designated Products).

As part of Argonne's commitment to comply with the EPA's Comprehensive Procurement Guidelines, the following conditions may affect your department or division:

- If your division or department purchases any of the EPA-designated items through the Procurement Department, the listed items may be replaced by products that adhere to the EPA guidelines for recycled content. In addition, once acceptable alternatives are identified, some products that do not meet EPA recycled-content requirements may no longer be available through the existing material ordering systems.
- If your division or department develops specifications for the use or application of any EPA-designated items, these specifications should adhere to the EPA guidelines for recycled content.
- If your division or department purchases any EPA-designated items through established blanket purchase agreements, your division or department shall, to the maximum extent practicable, select products that meet or exceed the EPA guidelines unless written justification is provided that a product is not available within a reasonable time frame, does not meet appropriate performance standards, or is available only at an unreasonable price. In addition, if these items are purchased through blanket purchase agreements, each division or department shall document these purchases and provide this documentation to the Pollution Prevention Program or the Procurement Department on a quarterly basis.

The Laboratory purchased many EPA-designated recycled-content products under EO 12873, including janitorial and office papers, plastic trash bags, toner cartridges, retread tires, and re-refined lubricating oils. The purchase of these and other recycled-content products have become commonplace at the Laboratory with little concern over product quality. Under the guidance of EO 13101, the types and amounts of recycled-content products purchased annually by the Laboratory will continue to increase.

2.8.2 Planned Actions

Planned actions are to review and update contractual requirements in accordance with the "mega-clause," and review and update, as necessary, the Affirmative Procurement Policy and EPA designated list.

2.9 Electronic Stewardship and Data Centers

The Laboratory has established the following goals to meet sound electronic stewardship and management of data centers.

Goal 1 - Desktop Computer Energy Consumption: Reduce the energy consumed by desktop computing resources by 50%.

Goal 2 - Data Center Energy Consumption: Reduce the energy consumed by local enterprise and local programmatic computing and storage services by 10% per year for FY 2011-14 (total reduction 40%). Enable programmatic divisions to deploy servers in centrally managed, high-efficiency data center space.

Goal 3 - Data Center Energy Practices: Develop Laboratory-wide requirements and guidelines for data center energy management and drive (a) centralization of new server deployments in high-efficiency Laboratory central data centers (implemented as "collocation space") and, where feasible, (b) use of commercial cloud services rather than locally operated servers.

Goal 4 - Data Center Metering: Install dedicated meters for all Laboratory data centers by FY 2012.

Goal 5 - Environmental Disposition Policy*:* Update Laboratory policy for environmentally sound practices for disposition of all excess or surplus electronic products by end of FY 2011.

Goal 6 - Double-Sided Printing: Update all shared copiers and printers to default to double-sided printing and copying by end of FY 2011.

2.9.1 Performance Status

Goal 1 - Desktop Computer Energy Consumption:

The Laboratory has evaluated several technologies for reducing desktop computer energy consumption. A pilot project has been initiated with approximately 75 systems and multiple types of users (administrative, technical support, scientific, etc.) across the Laboratory. Estimated desktop energy use for 5,000 desktop systems at $0.084/kWh is approximately $150,000/year. Evaluation of thin-client technology has been done multiple times over the past three years as technology has evolved. Argonne's assessment has found that tablet computers are a more realistic evolutionary path for the desktop, providing associated hardware and software infrastructure at lower cost.

Goal 2 - Data Center Energy Consumption:

The Laboratory enterprise data center has virtualized approximately 50% of its servers. For scientific servers, the Laboratory has evaluated commercial cloud services, finding that data transfer costs can readily offset savings as of FY 2010. However, commercial cloud services continue to drop in price and improve in performance. The current enterprise data center (Bldg. 221) is running at 95% of available cooling and is inefficient in that it cannot support modern energy management strategies such as airflow engineering. Modern, energy-efficient data center space at the Interim Scientific Supercomputing Facility (ISSF), established for the ALCF in FY 2009, is scheduled to become available as a central Laboratory enterprise and programmatic data center in FY 2014. Partial migration from legacy data centers can begin earlier based on space availability in the ISSF and pending investments in necessary additional power and cooling.

Goal 3 - Data Center Energy Practices:

Laboratory policies for data center and server energy management are outdated.

Goal 4 - Data Center Metering:

Most data centers are not directly metered; new data centers are partially metered but not to the degree necessary to calculate and track efficiency using standard industry measures.

Goal 5 - Environmental Disposition Policy:

Laboratory policy exists but is outdated.

Goal 6 - Double-sided Printing:

A minority of shared copiers and printers default to double-sided printing. Most shared copiers and printers are centrally managed, facilitating deployment of default settings.

Argonne Wins E-Star Award

An innovative, energy-saving approach to cooling Argonne's Blue Gene/P supercomputer was recognized with an Environmental Sustainability (EStar) award from the U.S. Department of Energy's (DOE) Office of Science (SC). E-Star awards highlight environmental sustainability projects and programs that reduce environmental impacts, enhance site operations, reduce costs, and demonstrate excellence in pollution prevention and sustainable environmental stewardship. Pete Beckman, director of the Argonne Leadership Computing Facility (ALCF) attributes the award to the very dedicated and talented team that works continually to reduce power consumption while supporting breakthrough science on the supercomputer and to the belief that green science is smart science. The Argonne project was one of just five E-Star awards given to DOE's SC laboratories. A total of 127 projects from across the country were nominated for the awards.

Much of the electricity needed to operate a supercomputer is used to cool the machinery. In colder weather Argonne saves as much as $25,000 per month in electricity costs by leveraging the Chicago area's climate to chill the water used to cool the supercomputer for free. That is in addition to the cost savings from the energy-efficient architecture of the Blue Gene/P, which uses about one-third as much electricity as a comparable supercomputer.

2.9.2 Planned Actions

Goal 1 - Desktop Computer Energy Consumption:

Guidelines will be developed in FY 2011 to implement energy reduction software on desktop systems. Estimated cost is $85,000 in year 1 and $15,000 annually thereafter, with an estimated annual savings of between 45% and 60% (with firm numbers expected in late FY 2011).

Goal 2 - Data Center Energy Consumption:

The Laboratory will continue to increase the percentage of systems that are virtualized. Beginning in FY 2011, virtualization or commercial cloud architecture will be required for all new enterprise business applications. A data center reduction team has also been formed to evaluate the elimination and consolidation of data centers.

Goal 3 - Data Center Energy Practices:

A Laboratory policy will be developed in FY 2011 to guide energy management for servers and data centers. This policy will include recommendations for use of central Laboratory data centers versus local data centers, as these become available approaching FY 2014 or earlier, if new central data center space can be conditioned. The policy will include minimum energy efficiency requirements for all Laboratory data centers.

Goal 4 - Data Center Metering:

All data centers, except those scheduled to be phased out by FY 2014, will be metered with dedicated meters by the end of FY 2012.

Goal 5 - Environmental Disposition Policy:

Laboratory policy will be updated through the Laboratory Management System (LMS) process.

Goal 6 - Double-sided Printing:

All shared copiers will be set to default to double-sided printing by the end of FY 2011.

3.0 Site Innovation

Argonne has long been an innovator in clean energy technology and climate change evaluation. R&D divisions throughout Argonne are currently working in many areas of sustainability, including energy storage, resource efficiency, electric transportation systems, alternative fuels, and solar energy. In August 2010, Argonne established a Sustainability Site Innovation team led by two of Argonne's leading programmatic researchers. The Site Innovation team's main mission is to interface with our scientists and engineers to develop ideas for deploying sustainability technology at the Argonne campus.

The team identified over 40 potential efforts that would help Argonne and DOE meet their sustainability goals. The concepts considered span operations and behavior; sensing, assessment, analysis, and control; pilot-scale testing; and full-scale deployment. The team has evaluated the most promising candidate ideas, resulting in the seven project proposals presented in Section 4.0 and Appendix A.

Our intent is to work with and share ideas with other organizations – national laboratories, government agencies, universities, and industry – to expand the benefits of sustainability innovation to the Argonne site and elsewhere. Where appropriate, we would license Argonne technology to firms that would deploy the technology through their customers.

Building IQ Makes Argonne Smarter about Energy Management

Argonne is working to develop cutting-edge energy management systems for commercial buildings that can potentially reduce energy intensity by as much as 30 percent. The Mathematics and Computer Science Division is leading a pilot project with *Building IQ,* an energy management software company, to improve energy performance at the Theory and Computing Sciences (TCS) building.

The partnership with Building IQ takes advantage of Argonne's expertise in the optimization of modeling and algorithms to develop next-generation energy management systems for buildings. These systems will use building dynamic models, weather forecasts, occupant sensors, meeting room scheduling, and price structures to optimize the building conditions (for example, maximizing human comfort while minimizing CO_2 emissions) in real time.

The researchers will use the 200,000 sq ft TCS building at Argonne as a "living laboratory" to test new systems. If successful, the new energy management system can be deployed in additional buildings at Argonne to form a powerful network that can coordinate with the central power plant and the utility company to minimize the energy intensity and carbon footprint of the entire site. This project is one of many underway at Argonne to help reduce greenhouse gas emissions and energy use across the Laboratory.

Appendix A provides detailed descriptions of seven proposals that were down-selected for further consideration from Argonne's Site Innovation Team. The proposals are:

1. Advanced Sensors and Control Systems for Site-Wide Real-Time Resource Management
2. Geothermal Systems with Heat Recovery Applications
3. Development and Testing of a Fully Superconducting Wind Turbine
4. Midwest Photovoltaics Analysis Functional Landscaping for Water Saving and Climate Change Adaptation Facility (MPAF)

5. Functional Landscaping for Water Saving and Climate Change Adaptation

6. Fuel Cell Applications with Waste Heat Recovery, Thermal Storage, and Renewable Fuels

7. Development and Testing of Carbon-Free Heating and Cooling through Solar Energy Collection and Storage

At this time, Argonne is evaluating which projects to begin on in FY 2011, using Laboratory indirect funding.

4.0 Management and Funding

4.1 Management

Figure 4.1 shows Argonne's sustainability program team organization chart. Dr. Paul Kearns, Deputy Laboratory Director for Operations, is directing Argonne's Sustainability Program Office. Dr. Mark Peters, Chief Research Officer and Deputy Lab Director for Programs, has been appointed as Sustainability Innovation Officer. Michael Dunn, Deputy Director of Facilities Management and Services, is the Sustainability Program Manager. Sub-teams have been created to align with the major program focus areas and are led by senior managers and scientists. Supporting the sustainability program is Argonne's core Energy Team shown in Figure 4.2.

4.2 Sustainability Funding in Overhead

Table 4-1: Actual and Planned Overhead Expenses

Summary of Overhead Funded Projects in CEDR Tab 5 ($K)

Category	FY10 Actual	FY11 Plan	FY12 Projected	FY13 Projected
Water	$20	$30	$50	$50
Energy Efficiency (non-data center)	$2,415	$360	$500	$500
Energy Efficiency (data center)	NA	$135	$300	$0
HPSB	$40	$75	$250	$500
Metering	$140	$650	$250	$250
Cool Roofs	$888	$1,000	$1,000	$1,500
Behavior Change	$5	$75	$75	$0
Lighting	$378	$658	$500	$500
All other	$239	$1,469	TBD	TBD
Total	**$4,125**	**$4,452**	**$2,925**	**$3,300**

4.3 ESPC/UESC On-going and Planned

Argonne has three ESPC delivery orders presently in the performance stage that are summarized in Table 2-1. A new ESPC is in development for construction of a CHP plant. The project kickoff meeting with DOE-Argonne Site Office (ASO) and FEMP has occurred, and all parties are working to make an award by August 2011. Construction on the plant would not likely commence until calendar year 2012.

4.4 Funding Sources and Return on Investment

Our plan does include continued use of ESPC financing for two major efforts; the CHP plant and a site-wide energy savings contract. Other sources of funding include Institutional General Plant (IGPP) and Major Repair (MR) funding.

Argonne's energy savings reinvestment program is another source of funding. In a little over two years the program already generates over $500K in savings for investment in sustainability and energy projects. The Laboratory uses ROI as the main criterion for selecting projects under this program. The FY 2011 budget also includes a $550,000 indirect line item for sustainability, funding for advanced meeting and for CHP project support prior to ESPC award.

To assist funding sustainability initiatives, Argonne plans to develop an Energy Information System (EIS) built upon advanced metering and real-time energy data to provide critical information that can be used to drive load shedding or load shifting. Load shedding can be used to drop demand charges that typically make up 10% to 20% of a customer's power bill. Load shifting involves running high-power consumption operations (e.g., chillers, high performance computing routines) during off-peak hours to take advantage of rates that are 50% to 70% less than peak daytime rates. Argonne has already taken steps to improve capabilities in this area. Some advanced metering has been installed and the CIS division is spearheading an effort to develop the EIS. The Laboratory also recently hired a full-time energy analyst to evaluate energy use data and provide guidance to key personnel, such as plant operators, building engineers, and building managers.

Argonne also participates in a load shedding program with utility providers. As part of this program, Argonne periodically sheds load and switches demand to standby generators to demonstrate grid relief capabilities. The success of those efforts brought approximately $480,000 in rebates to the Laboratory.

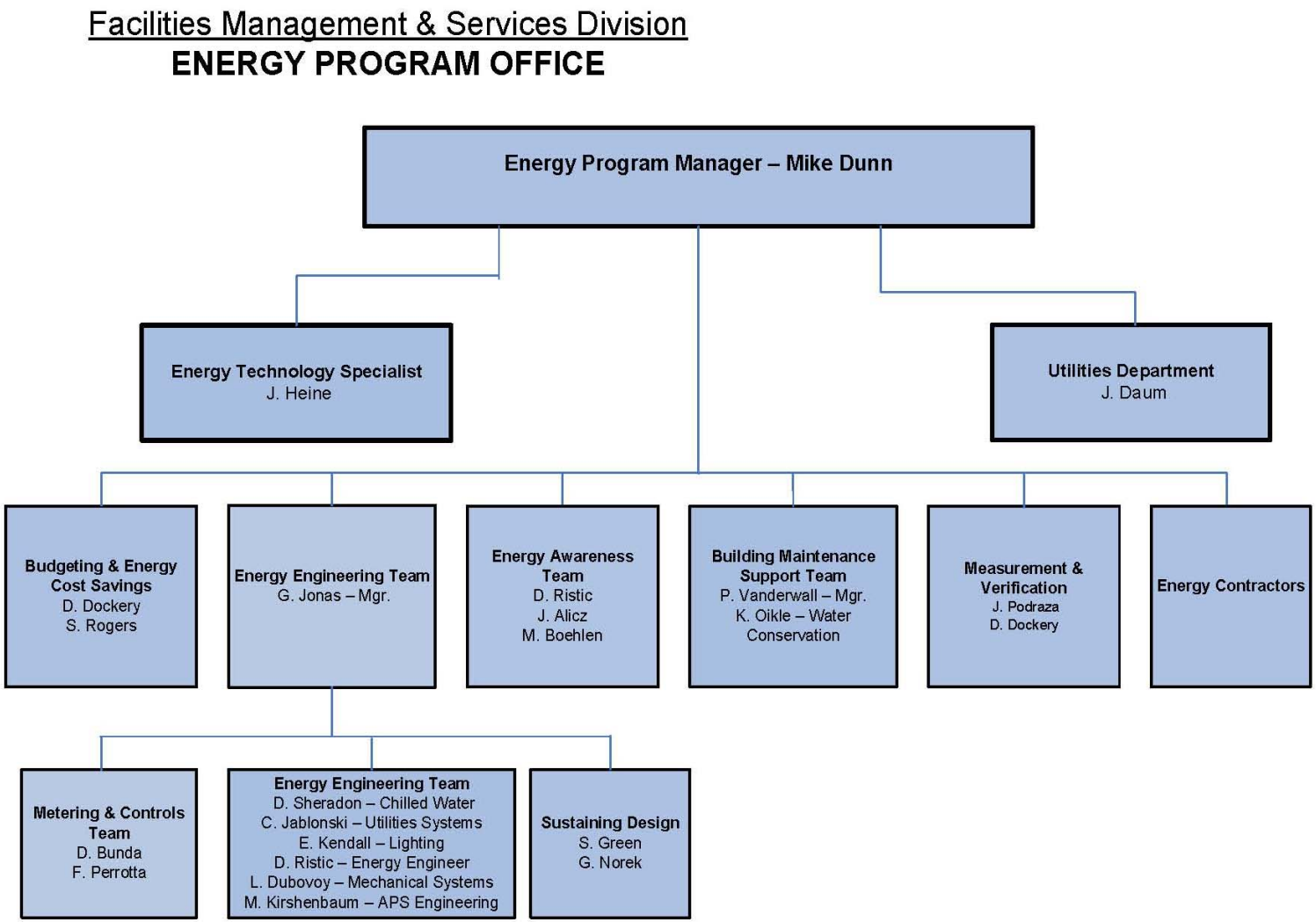


Figure 4-1: Energy Program Organization Chart

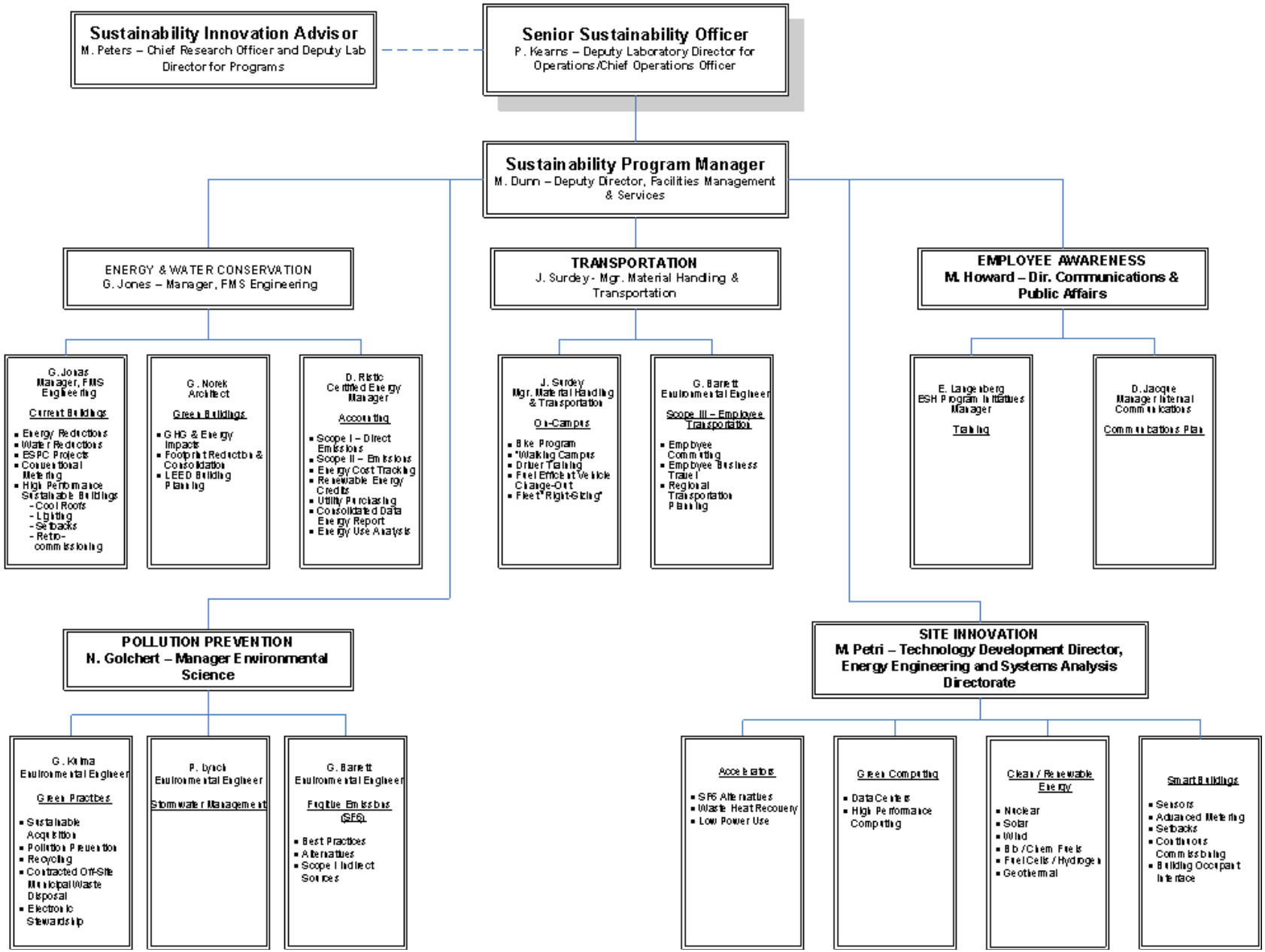


Figure 4.2: Argonne National Laboratory Sustainability Program

5.0 Adding Supply and Purchasing Renewable Energy Credits

Figure 5-1 shows Argonne's projected GHG emissions (in MT CO2e) factoring in planned growth as well as planned reduction initiatives.

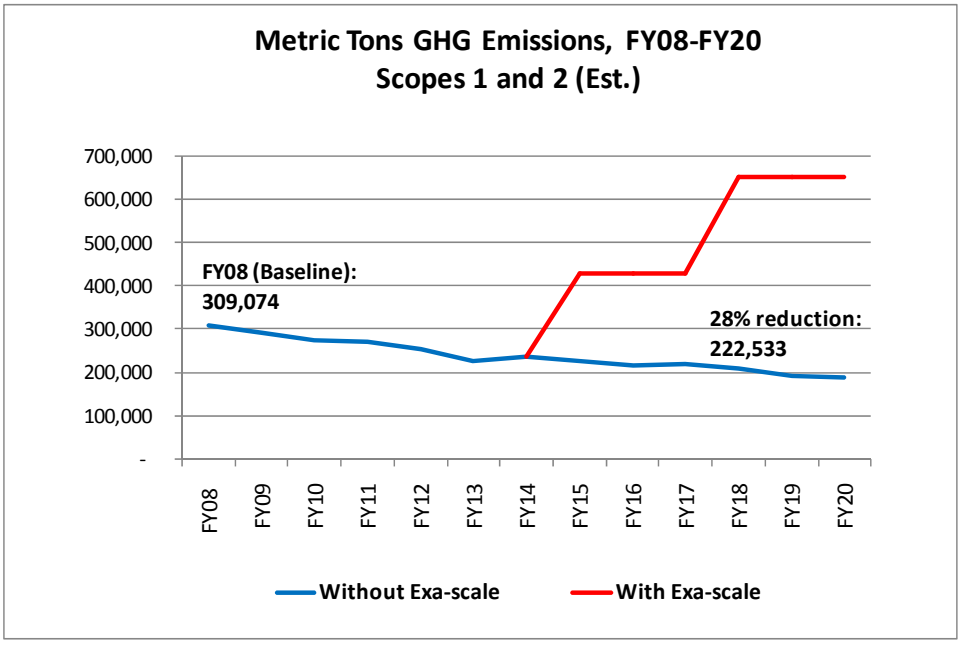


Figure 5-1: Projected GHG Emissions FY 2008 to FY 2020

To offset the growth, especially that related to exascale computing the Laboratory is considering three options. The first, and most desirable from a true sustainability standpoint, would be to generate the power on site. This is followed by a dedicated purchase power agreement for clean or renewable energy and finally, by purchase of Renewable Energy Credits. The following sections discuss those three options.

5.1 On-site Power Production

As explained in Sections 2.1.2, Argonne is continuing evaluation of a number of renewable energy production alternatives, including wind, solar, geothermal, and biofuels. At this time, specific information on costs and sizes of systems are still in development; however, initial projections are in excess of $70 million for a 10 MW to 15 MW solar and/or wind energy systems. Argonne has begun discussions with NREL and FEMP to update previous studies on on-site renewable energy conducted in 2008. The FY 2012 SSP is expected to provide much firmer estimates and plans on on-site renewable energy.

The CHP plant scheduled for FY 2013 construction is anticipated to provide 5.8 MW of power; however, that is much less than is needed to support major high performance computing needs like exascale. Due to Argonne's heat demand it is not practical to size the CHP for higher power production.

5.2 Purchasing of Off-Site Dedicated Renewable or Carbon Free Electricity

Argonne is aggressively pursuing the feasibility of Purchase Power Agreements or other type of contractual arrangements with local clean/renewable power producers. Presently, credit for such

purchases cannot be taken due to regulations requiring use of e-Grid emission factors for electricity purchase. Argonne has drafted a white paper on an alternative approach and is presently circulating it to other DOE-SC labs for review and comment. There are a number of wind and nuclear power providers in the area that could be a good fit for a dedicated purchase power arrangement. Exelon Corporation, Argonne's new power provider effective February 2011, in fact has already established an "Emissions Free Energy Certificate" program that the Laboratory could take advantage of. Argonne has also renewed contact with FEMP and NREL to learn more about purchasing options/programs for both off-site and on-site renewable power. These types of options are our second tier of preference to support Argonne's HEMSF growth plans.

5.3 Purchasing Renewable Energy Credits (RECs)

To assist DOE in meeting its renewable energy goals, Argonne purchased RECs equal to 5% of electricity consumption in FY 2010 from wind and biomass energy producers. Contract work is underway to procure an additional 7.5% of power consumption via RECs in FY 2011.

As discussed previously, power demands are expected to dramatically increase with the installation of exascale computing systems installations are scheduled for FY 2015 and FY 2018. Although the preferred choice would be to offset GHG emissions through on-site production of renewable energy. Figure 5-2 indicates that offsets through REC purchases are relatively affordable compared to comparable construction of wind and/or solar systems[4].

	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20
RECs Purchase Plan (MWh)	13500	28984	27106	24130	25444	287091	303213	297107	631060	653808	661469
Unit Costs	$1.40	$1.54	$1.69	$1.86	$2.05	$2.25	$2.48	$2.73	$3.00	$3.30	$3.63
Total Costs ($K)	$19	$45	$46	$45	$52	$647	$752	$811	$1,894	$2,158	$2,402

Figure 5-2: Projected REC Purchases Required to Meet Exascale Power Demand

[4] For planning purposes, REC prices are projected to increase 10% annually. Prices will likely be highly influenced by State Renewable Portfolio Standard Requirements and any state or federal legislation of greenhouse gas emissions.

Appendix A – Site Innovation Proposals

A-1 Advanced Sensors and Control Systems for Site-Wide Real-Time Resource Management

This project will develop an advanced sensor and control infrastructure for site-wide energy management.

A-1.1 Project Description

Real-time sensing of key operational variables in buildings, steam boilers, chillers, and HVAC systems; electricity, fuel, and water demands; CO_2 concentrations; and occupant behavior is critical to managing site-wide resources in an efficient manner. The first requirement is low-cost sensors that can be deployed at a large scale. In addition, the complex interrelations among facilities and resources require advanced model-based control systems able to absorb sensor data to learn and predict site efficiency as operational variables in individual systems change. These predictive capabilities can then be exploited to adjust operational variables to minimize resource consumption automatically and to map individual building and occupant behavior into site-wide performance metrics such as CO_2 emissions and electricity demands. Argonne's researchers, in collaboration with industrial and university partners, will provide the necessary sensor technology, communication infrastructure, and control systems to achieve significant resource savings. Partners include Johnson Controls, DuPage Water Commission, Building IQ, Illinois Institute of Technology, Loyola University, and University of Chicago. A total floor space area of 2,000,000 sq-ft (equivalent to 10 buildings) will be covered in this project to demonstrate the potential of the technology. The project will provide both environmental and economic savings, and will support current research initiatives in building technologies, a growing area at Argonne. In addition, the system will provide Argonne with capabilities to perform automatic site-wide demand-response.

A-1.2 Technical Risks

This is an integrative project that builds mostly on existing and low-risk technology. The associated risks are mainly related to operational constraints encountered in the deployment phase that could slow project completion.

A-1.3 Relevance to Argonne's R&D Mission

This project will provide a comprehensive mix of computing sciences and engineering insight that will result in novel concepts to manage resources in large facilities. Such a comprehensive set of tools does not currently exist. The resulting technologies can be deployed in individual government and commercial buildings and sites and can be potentially licensed. The project includes collaborators from multiple programmatic (MCS, DIS) and operations (CIS, FMS) and will expand the capabilities of the building technologies program at Argonne, consistent with current DOE-EERE goals.

A-1.4 Environmental Benefits

According to Building IQ, automatic energy management can save 20-30% in heating/cooling electricity in the demand of electric air-handling units. Similar savings of 10-20% can be expected for steam in steam-run air-handling units systems. According to Efftrack, a chiller optimization company, savings of 10-20% in electricity demand can be expected by more efficient chiller performance. Such savings are critical to Argonne, given high chiller demands for high-performance computers and the Advanced Photon Source (APS).

An additional estimated reduction of 10-15% in lighting and computing demand can be achieved by sensor deployment and by providing real-time information to occupants. We estimate that the year-round electricity savings can go beyond 30% in each building by deploying novel sensors and control systems.

For the current implementation of the Building IQ system at the Theory and Computing Sciences (TCS) building (entire floor space of 200,000 sq-ft), we have estimated savings in the range of 1,000 MT/yr of CO_2. Our estimate is conservative and considers 30% of the total electricity demand going to the HVAC system (chillers and air-handling units) and savings of 25% from automation. In the project proposed here, we plan to cover an area equivalent to 10 TCS buildings, which will include buildings such as Center for Nanoscale Materials (CNM), Chemistry (203), and the APS area (400 area). A technical feasibility phase will be executed to determine the most suitable buildings. The expected total savings are around **10,000 MT/yr of CO_2**. The current site-wide CO_2 emissions from electricity are around 200,000 MT/yr of CO_2. Consequently, **the total CO_2 savings resulting from this project would be 5% of current side-wide emissions**. If successful, the project can be scaled over the long run to reach savings levels of 10% by deploying over larger spaces and through the implementation of other technologies. The installed infrastructure of this project will support an easier deployment in additional buildings.

The total annual electricity cost savings at the TCS building are approximately $50K. For the equivalent area considered **in this project, the cost savings would be around $500K/yr**. The savings in CO_2 and cost will be further expanded by savings of steam in steam-run heating systems. Water savings are estimated on the range of 10% of the current total water consumption of 150,000 gallons/yr. The potential water cost savings are around $30-50K/yr. Finally, since the system will provide a capability to perform automatic demand-response, additional significant cost savings are achievable during these events. The magnitude of these savings is subject to testing.

A-1.5 Estimated Schedule and Cost

The project will be split into three parallel subtasks. Initial project planning for the integrated project (January 2011) will require $50k in effort costs. Each subtask is detailed below along with costs for each of two phases (development and implementation).

1. **Sensors**: Low-cost building sensors.
2. **Modeling and Controls**: Real-time resource management system.
3. **Interfaces and Feedback**: Analytics and real-time occupant information and feedback interfaces.

Project planning

Time: January 2011
Cost: $50K

Project Development, Prototyping, and Limited Implementation

1. ***Sensors*.** Set-up of central Johnson Control's Metasys building management system for site-wide sensor data collection. Assessment of existing and needed sensors and power meters in pilot buildings for the site-wide resource management system. Development of low-cost building sensors for light, temperature, and humidity. **Time:** January 2011-June 2012 (18 months). **Cost:** $300K.

2. ***Modeling and Controls*.** Initial installation of Building IQ's energy optimization system in air-handling units of pilot buildings. Extension of capabilities for new sensors, chillers, boilers, and multiple resources (natural gas, water, etc.). Development of site-wide resource management system. **Time:** January 2011-December 2012 (18 months). **Cost:** $500K.

3. ***Interfaces and Feedback*.** Development of analytics and in-office displays for occupant information visualization (weather, energy performance statistics, pie-charts, what-if scenarios, etc.) and feedback to building control system (comfort status). **Time:** January 2011- December 2011 (12 months). **Cost:** $350K.

Project Implementation

1. ***Sensors*.** Deployment of sensors and connection of Metasys systems in pilot buildings. Training of Argonne FMS maintenance personnel to monitor sensors and network. **Time:** June 2012-December 2013 (18 months). **Cost:** $300K.

2. ***Modeling and Controls*.** Final implementation of building and central control systems. Building and site-wide performance analysis. Site-wide simulation studies under demand-response scenarios and extreme weather conditions. **Time:** December 2012-December 2013 (18 months). **Cost:** $500K.

3. ***Interfaces and Feedback*.** Deployment of interfaces, analysis, trending of data for performance evaluation (for both management/operations and occupant use). Analysis of occupant behavior and feedback to real-time information. **Time:** December 2011-December 2012 (12 months). **Cost:** $350K.

Project Schedule

	CY 2011				CY 2012				CY 2013			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Planning												
Development												
Sensors												
Modeling & Controls												
Interfaces & Feedback												
Implementation												
Sensors												
Modeling & Controls												
Interfaces & Feedback												

The implemented system will be operated permanently and monitored by Argonne researchers and operational staff. The system can be expanded to manage more buildings and to incorporate emerging technologies such as battery storage and geothermal, wind, and solar supply.

The total cost of the three-year project is $2.4M. Upon deployment, the running costs of the system will be $100K/yr with savings of $530K/yr which represents net savings of $430K/yr. The estimated return on investment is 5.5 years.

A-2 Geothermal systems with heat recovery applications

The goal of this project is to advance geothermal science and its applications to energy storage when coupled with large-scale heat recovery and seasonal thermal storage. The use of ground water at Argonne can provide an economical means of tapping into geothermal sources for facility heating and cooling, which will serve as a tool for analysis and advancements in geothermal technology.

Based on the research conducted for this project, a fully functioning working prototype could be constructed that would result in a significant reduction in Argonne site thermal energy usage, greenhouse gas emissions, and industrial water use.

A-2.1 Project Description

Geothermal systems use groundwater's significant thermal storage reservoir to provide heating and cooling for both facility and process applications. Coupled with the storage and recycling of excess facility heat, these systems can have a major impact on reducing the energy consumption and carbon footprint of facilities that are large consumers of thermal energy. These facilities include light sources, laboratories, particle accelerators, computing facilities, hospitals, high density office buildings, and processing plants.

Geothermal systems can be divided into two main types: closed and open loop systems. Closed systems (also known as ground-coupled heat pumps) require buried heat exchangers that often consist of large underground piping networks. The cost of these heat exchangers weakens the economic case for ground source heat pump (GSHP) systems. Open loop systems pump ground water from and then back into an existing aquifer, thereby eliminating the need for underground heat exchangers and greatly reducing capital costs. For open loop systems to provide effective performance, the determination of well separation intervals and injection patterns is critical. These parameters are influenced by a number of factors including thermal conductivity, soil permeability, and ground water migration, and are further complicated when used as part of a seasonal Aquifer Thermal Energy Storage (ATES). Methods for designing open loop systems are not fully developed and require additional research and refinement.

This project includes the further development and refinement of these design methodologies. Moreover, this project will assess the thermal and geologic properties of the Argonne site reservoirs to establish the feasibility for (1) the use of the aquifer as a heat sink for process cooling and as a replacement of evaporative cooling towers used for conventional cooling, (2) the use of the aquifer for seasonal energy storage as a primary source of site facility heating, and (3) the opportunities to access additional geothermal resources on site. The underground storage of thermal energy would support a research effort to explore the potential for the recycling of heat from summer cooling to winter heating applications. This will provide much needed operating data in the nascent field of ATES systems. Improved understanding of the thermal properties of the reservoir and underlying geology would also aid research in the mapping of national geothermal power generation potential, which is generally lacking for Illinois and areas surrounding Lake Michigan.

A geothermal system that combines the heat sink potential of the aquifers with their heat storage capability could result in the future construction of a series of AETS systems across the Argonne site. This system, when supplemented with heat recovery machines, would have the potential to offset a substantial portion of the process cooling currently being provided by mechanical refrigeration and become a primary heat source for the laboratory through energy reclamation. It is estimated that a series of AETS systems could provide the majority of the laboratory's yearly heating demand of approximately 180,000 MW-hrs of equivalent energy. This would result in a yearly reduction of between 12,000 to 25,000 equivalent metric tons of CO_2.

This project consists of five stages for the characterization of site aquifers, the design of the AETS and associated heat pump systems, the demonstration of a full-scale prototype system, and the site-wide deployment of AETS systems:

1. ***Stage 1*** will consist of a geological and hydrological site assessment.

2. ***Stage 2*** will consist of the development of the ATES model with provisions to examine various operational scenarios.

3. ***Stage 3*** will include optimization of the ATES model, including a small pilot system to be used to validate the model.

4. ***Stage 4*** will include the construction of a full-scale prototype in the APS complex (the 400 area).

5. ***Stage 5*** will consist of the site-wide deployment of proven ATES system technology.

This Stage 4 prototype system should reduce APS energy consumption by 13,000 MW-hrs per year (equivalent), reduce Argonne greenhouse gas emissions by 2,800 metric tons of CO_2 per year, and industrial water use by 60 million gallons per year. In addition, the prototype system will save an estimated $600,000 per year in energy and water costs while providing a full working system for further research and data acquisition for enhancement of the system design and operation. The operating system will be constructed to vary water extraction and injection points in both horizontal and vertical directions while altering the overall pattern of water flow over a defined three-dimensional grid. Heat pump equipment will be configured to permit variations in flow rates, operating water temperatures, and refrigeration methods to study and optimize system performance. Based on the estimated cost of construction, this system will have a simple payback of 6.8 years.

Based on the results of the prototype, additional systems would then be installed throughout the Argonne site (Stage 5) as part of plans for new building construction and rehabilitation of existing buildings. A fully functioning site-wide network of AETS systems could result in a net energy savings (based on current site energy usage) of 170,000 MW-hrs (equivalent) with a greenhouse gas savings of 12,000 to 25,000 metric tons of CO_2 equivalent. Further, the site-wide deployment would result in saving over 100,000,000 gallons per year of industrial water and 10,000,000 gallons per year of disposal costs (cooling tower blow down).

A-2.2 Technical Risks

Technical risks include the potential for mechanical equipment failure, unanticipated water quality issues, material corrosion, and the inability to generalize results for other site applications with differing geo-hydrological and soil conditions.

A-2.3 Relevance to Argonne's R&D Mission

The design, development, and operation of this technology will further the Argonne's efforts in geothermal science and engineering, thermal energy storage, water and waste water management, and provide a strong framework in the national effort to develop net-zero-energy buildings.

A-2.4 Environmental Benefits

The prototype system, based on a geothermal system with 12,000 MW-hrs of storage and a 1,000 ton heat pump, will result in a savings of approximately 2,800 metric tons equivalent CO_2 and 60,000,000 gallons of industrial water per year.

The full site deployment will result in the saving between 12,000 to 25,000 metric tons equivalent CO_2 and in excess of 100,000,000 gallons of industrial water per year.

A-2.5 Estimated Schedule and Cost (based on a 1 MW system)

Research Stages - Stages 1 through 3:

Item	Time	Cost	Comments
Stage 1- Site Assessment	4 months	$ 90,000	
Stage 2 - ATES model development	8 months	$150,000	
Stage 3 - Optimization of ATES model	6 months	$400,000	
Total Cost		**$640,000**	

Full-Scale System Design and Construction - Stages 4 and 5

Item	Time	Cost ($1000)	Comments
Stage 4- Prototype Area 400 System	11 months	$ 4,100	Operation should result in $600,000 per year cost savings, 2,800 metric ton CO_2 reduction, and 60,000,000 gal per year industrial water reduction, with a 7-year simple payback.
Stage 5 - ATES deployment across ANL site, starting with Areas 200 and 300	Phased multiyear effort to be coordinated with Argonne new building development and rehabilitation plans for existing buildings	$25,000	Stage 5 will result in an estimated $3,000,000 cost savings, 12,000 to 25,000 metric tons of CO_2 reduction, with a 7-year simple payback.

Once constructed, the system should have a life expectancy greater than 25 years.

A-3 Development and testing of a fully superconducting wind turbine

Argonne will partner with a small company to develop a small-scale demonstration of next-generation wind-turbine technology based on direct-drive fully superconducting generators, which eventually could lead to cost-effective 10-MW units appropriate for off-shore wind farms.

A-3.1 Project Description

The long-term goal is the development of wind turbines in a new power regime ~10 MW each with application in the emerging field of off-shore wind. The proposed enabling technology is

fully superconducting, direct drive generators based on an intermediate-temperature superconductor such as MgB_2 operating at 20-30 K. The new robust magnet technology that will greatly reduce the wind turbine mass through the elimination of the gear box is being developed by a small company, Advanced Magnet Laboratory (AML), in Palm Bay, Florida. A collaboration involving this company, Argonne, and Fermilab is proposed to develop smaller-scale prototype turbines in the 2 MW range for testing at the Argonne site. The first demonstration of this new approach, possibly based on proven conductor such as Nb_3Sn, should be realizable in three years from project initiation. A second phase of this development would be to monitor and assist in the development of MgB_2 conductors with the goal of demonstrating direct-drive superconducting on-land turbines with rated power up to 5 MW before 2020.

Effectively using wind power in this region of the U.S. requires a further refinement of wind turbine design. The AWS wind resource map of this region of Illinois shows that the average wind speed is 6 m/s at 80 meters, an IEC wind classification between III and IV. A standard small turbine produced by GE in large numbers is the 1.5xle, rated at a peak power of 1.5 MW and optimized for IEC class III. This turbine with an 80-m hub height and 82.5-m rotor diameter produces 400-kW output at wind speed of 6 m/s. Many turbine designs now use hub heights in the 120-m range and rotor diameters of well over 100 m. We propose to monitor the wind speed and turbulence distributions at heights of 100 to 150 m at Argonne and Fermilab and to collaborate with one of the large turbine manufactures to make the optimal choice of hub height and rotor diameter to achieve the most cost-effective performance in our relatively low wind speed classification. We expect a higher hub height and rotor diameter to yield a higher capacity factor, possibly in the 30-40% range. Hence, by ~2015 it is possible that with three 2-MW peak-power superconducting turbines installed at Argonne with a capacity factor of 33% the electrical output would be 2-MW average, reducing the Argonne emissions by about 15,000 tons of CO_2 equivalent per year.

By 2020, with the addition of 2 or 3 larger (5-MW) turbines, the savings could triple to ~45,000 metric tons CO_2 equivalent per year if an appropriate load leveling scheme is developed. A scenario for utilization of the additional ~15-MW peak electrical power (~5-MW average wind-generated electrical power) is in the operation of the chillers required for the next-generation exascale computing facility. A load-leveling scheme using large-scale energy storage by means of ice and water can be investigated for feasibility.

A-3.2 Technical Risks

There are cost uncertainties associated with the deployment of a new generation of wind-turbine technology at the relatively small scale proposed. There is also a technical risk that the development of the MgB_2 superconductor may not be fully successful and that the alternate conductors are significantly more costly. There is risk that this relatively large-scale application of cryo-cooler technology for 10-30 K operation of the Nb_3Sn initially and the MgB_2 later will lead to long-term maintenance and reliability issues. There is also some risk in the development of load-leveling scenarios to smoothly compensate for output variations from the turbines.

A-3.3 Relevance to Argonne's R&D Mission

The magnet technology proposed is a direct spin-off of developments for high-energy and nuclear physics and is of high interest to scientists and engineers in these fields. Similarly the large-scale applications of new higher-temperature superconductors is of interest to the materials scientists that have made these developments possible. Argonne is a major node of the Center for Emergent Superconductivity, an Energy Frontier Research Center with Brookhaven and University of Illinois at Urbana-Champaign. There are many aspects of the development of reliable and economical large-scale wind power systems that require complex

systems engineering that is within the mission of Argonne's DIS Division. This project seems ideally suited for a Department of Energy multipurpose laboratory such as Argonne.

A-3.4 Environmental Benefits

At its full scope this project has the potential to reduce Argonne's greenhouse gas emissions by 45,000 metric tons CO_2 equivalent per year, which is about 15% of the present annual number, with a corresponding savings of 6 MW average electrical power. In addition on-site wind turbines would save a significant amount of offsite water that would otherwise be used in the generation of electrical power by conventional gas, coal, or nuclear power plants.

A-3.5 Estimated Schedule and Cost

Argonne estimates that the first ~2-MW prototype fully superconducting wind turbine will require about three years and $15M. In addition, site-specific project planning, wind-data collection, and systems analysis is likely to cost ~$2M. This can be carried out mostly in parallel with the prototype development.

Large-scale land-based wind farms cost in the neighborhood of $1-2M per installed MW of capacity. Based on that rule of thumb, and taking the high side because of this relatively small scale application, the three 2-MW and three 5-MW turbines may cost in the range of $40M. The savings in electricity cost per year would be about $5M, helping to offset the development and construction investments.

The full project will require about 10 years to complete.

Operation and maintenance costs are likely to be less than for conventional wind parks since by far the most maintenance intensive components of present-day wind turbine systems is the gear box. Overall, the operations costs should be in the range of 10-20% of the savings on electrical power costs.

The design lifetime of the equipment is expected to be 20 years or more.

A-4 Midwest Photovoltaics Analysis Facility (MPAF)

The Midwest Photovoltaics Analysis Facility will be an array of differing photovoltaic panel technologies located on Argonne’s Building 201 that will be designed both to provide green energy and to collect and analyze unprecedented real-world, comparative performance data.

A-4.1 Project Description

The Midwest has a surprisingly valuable solar resource that is vastly unexploited. Expanding the utilization of solar energy in this region, however, first requires a reliable understanding of how solar (photovoltaic) technologies perform under environmental conditions specific to the Midwest. *These data currently do not exist*. Information generally available includes how technologies perform under highly controlled, standardized laboratory conditions. Although this information is critical for scientific research and development, it does not translate directly to real-world utility. The Midwest Photovoltaics Analysis Facility (MPAF) is a means to fill this need, providing both the private and public sectors with objective technology performance information.

Argonne proposes to establish a photovoltaics analysis facility involving the installation, operation, and monitoring of various photovoltaic (PV) technologies on a building at the laboratory with one or more future satellite facilities elsewhere in Illinois. The building at Argonne, Building 201, is the headquarters of the U.S. Department of Energy (DOE) Office of

Science - Chicago Office (SC-CH). It houses both Argonne administrative and DOE personnel. Built in 1982, it was physically oriented and designed for optimal solar energy exposure and has structures for mounting solar panels. However, due to budgetary constraints at the time, no solar energy devices were installed. The solar panel mounting structures were instead turned into sun screens for the building. The proposed project is an opportunity to realize the original intended purpose of these structures, to implement a system for analyzing effectiveness of commercial and next-generation PV technologies unique to the Midwest, and to provide a high-visibility renewable energy installation. Furthermore, because even within the geography of Illinois weather and sunlight can vary considerably, one or more satellite facilities will be installed elsewhere in Illinois in later phases of the project to provide complementary data to the prime site at Argonne. Data from the satellite facility(ies) would be sent in real time to a central database located at the Argonne site for analysis.

Solar PV panels of various technologies will be studied, and a weather instrumentation package will be installed on the mounting structure that will measure variables such as solar insulation, temperature, precipitation, and wind speed/direction. A second weather package will be located near the building to measure conditions at standard heights and conditions. This will help correlate near-ground conditions to ones at the panels, providing valuable information for the analysis of future installations where only standard meteorological data are available. Monitoring devices will record information including voltage and current at the service entrance along with solar production, solar insulation, and weather conditions. This monitoring and data collection system time-stamps information and uploads it to a database and other data management software technology. The data collection system will capture real-time market Locational Marginal Prices (LMPs), ComEd system loads, and Laboratory loads that are monitored by smart meters. All data will be stored on electronic devices for analysis purposes. PV production will be displayed on monitors in the lobby of the building and the data will feed to the Argonne website.

Through the collected data, the grid implications of PV systems will be analyzed and PV grid integration issues will be identified. The analysis will quantify and correlate PV production to both Laboratory and ComEd loads. Using probabilistic techniques that estimate power system reliability parameters such as loss-of-load probability and unserved energy, the amount of new capacity that will be replaced by the PV system will be computed. Energy produced by the PV system will replace grid generation. The types of energy sources displaced by PV will be assessed on a seasonal basis from a systems perspective. Assessments will quantify changes in:

- Overall energy production (kWh) by thermal power plant type.
- GHG emissions and the emissions of air pollutants such as sulfur dioxide and particulates.
- Total production and marginal cost as a result of PV energy production.
- The economic value of PV capacity.

The analysis will be scaled up to evaluate the power-system effects of larger-scale solar PV at the Laboratory and, more broadly, in the State of Illinois and across the Midwest. Grid integration issues include load ramping impacts and correlation of PV production to hourly changes in system load as well as PV variability issues (time scales: cycle, seconds, minutes, hours, seasonal). This project will also merge new and innovative power system software with solar forecasting techniques to alleviate grid integration issues associated with PV production variability and uncertainties.

Current PV technologies, based primarily on silicon and CdTe modules, will ultimately be limited in their market penetration owing to high costs and material scarcity. There are a variety of promising next-generation technologies based on low-cost fabrication methods and abundant materials being developed at Argonne, other research institutions, and across the industry. The proposed Midwest Photovoltaic Analysis Facility will provide an ideal platform by which to investigate the real-world performance of these materials (to complement Argonne's extant capabilities to perform analysis under standard laboratory conditions) and benchmark them against existing technologies.

Argonne has several studies currently in progress that complement the proposed project. Future potential projects related to this proposal include investigations of the economics of PV and battery storage systems for load shifting and synergy between solar and wind production.

Project objectives include:

1. ***Collect data on PV performance in the Midwest*** – PV production and meteorological data collected during the project will be used to assess technology-specific performance, reliability, and degradation under climate conditions found in Illinois. Since several technologies will be installed, the ones that are best suited for climatic conditions in the Midwest will be determined. Results from the Argonne experience will be presented at scientific conferences, potentially paving the way for others in Illinois and the Midwest to install cost-effective PV technologies. Moreover, this facility will provide a platform for commercial entities to explore the performance of their current and in-development systems under real-world conditions with direct comparison to existing technologies.

2. ***Analyze financial and economic benefits of PV systems*** – The economic value of this energy to the grid will be computed based on time-of-day energy production and the corresponding LMP of electricity at the various PV sites. Using probabilistic models developed at Argonne, the firm capacity credit of the PV system will also be estimated, the value of which can be estimated from the going rates in the capacity market.

3. ***Promote awareness of PV systems through public outreach*** – Public outreach programs at the Laboratory and satellite locations can showcase PV systems to the general public. Argonne currently conducts site tours for citizen groups, business executives, and federal and state government decision makers. Public awareness can be further increased by posting real-time PV electricity production and other data on the Argonne and regional university web sites. During the August 2009 open house, approximately 20,000 people visited the laboratory. The university PV sites will expose not only the next generation of engineers, scientists, and decision makers to PV technologies, but also international and domestic visitors to the universities.

4. ***Complement and provide synergy with other Argonne projects*** – This project will provide a platform for the testing and analysis of novel PV technologies being developed at Argonne as well as integrating PV with energy technologies such as energy storage devices, smart grid, and plug-in hybrid electric vehicles.

5. ***Provide green electricity for Argonne and the satellite sites*** – A PV system will provide the sites with a source of carbon-free electricity, thereby reducing greenhouse gas (GHG) emissions, the consumption of fossil fuels, and the emission of pollutants such as sulfur dioxide, nitrogen oxide, and particulates. It will help Argonne meet its renewable energy goals and help the universities meet goals outlined in the Illinois Sustainable University Compact.

6. ***Create local-area jobs*** – By installing, operating, and maintaining the PV system and scientific equipment, the project will help create and retain jobs in Illinois. Additional Illinois jobs will be created by research and development and data collection and analysis activities. It is also anticipated that the project will act as a springboard for other solar and green energy related projects, which may create even more employment in Illinois.

7. ***Education of students at higher education institutions*** – Because of the co-location of proposed satellite facility(ies) with universities, students will be exposed to state-of-the-art renewable energy technology and analysis, which will help prepare them for future jobs in the green economy.

A-4.2 Technical Risks

The technical risks associated with MPAF are minimal as the support structure is already in place and the technologies are all commercially available.

A-4.3 Relevance to Argonne's R&D Mission

Argonne is a recognized global leader in the development and applications of power market simulation models and the analysis of strategic power systems issues. Argonne's software tools are used extensively by power industry participants, including regulators, system operators, transmission companies, and power generators. In supporting its clients in the U.S. and abroad, Argonne draws on over three decades of experience in systems analysis, electricity market and power systems modeling, system operations and dispatch analysis, investment planning, integration of renewable energy sources, and development of decision support tools.

Moreover, Argonne has recognized solar energy as a strategic research direction, and MPAF will provide a platform through which to analyze commercial technologies and to benchmark technologies that are produced as a result of solar research at the Laboratory.

A-4.4 Environmental Benefits

In the baseline scenario, the sunshade area located in front of the Building 201 lobby would be populated with ~63 PV panels. Assuming a 170 W average peak power for each panel, this corresponds with a system capacity of 10.7 kW. Presuming 5 hrs/day of collection, this system would produce 20,000 kWh/yr of clean electricity, saving 14 MT CO_2/yr. The baseline scenario could be expanded to include the full length of the building on the topmost set of shades (lower rows are shadowed by trees) for a total system size of 111 panels at 19 kW capacity.

A-4.5 Estimated Schedule and Cost

- Project planning - $5,000.
    - Months 1-2: Program design and specification.
- Project construction - $95,000.
    - Months 3-4: Procurement of equipment.
    - Months 5-10: Deployment of commercial photovoltaic systems.

- Project implementation - $5,000/yr.
    - Months 10-11: Verification of logging system and initial analysis of technology performance.
    - Months 11-12: Public outreach events to educate regional students and the public about solar energy.

Expected system life: 25-30 years.

A-5 Functional landscaping for water saving and climate change adaptation

This project will site-test multifunctional landscaping concepts to obtain a climate-change-resilient, site landscape that is native and efficient at using storm water runoff and other used water. This project will also serve as a research test bed into the adaptive traits of native plants and biofuel crops to survive extreme weather events in this region (such as droughts and flooding) and provide the basis for future work in plant genomics.

A-5.1 Project Description

We propose to grow a new tree farm on site at a location where it could be fed storm water or effluent from the wastewater treatment plant. As a control, we propose to identify a similar-size area on site where the same plants could be grown without any external water input. Additionally, we propose to team up with the Morton Arboretum and the Chicago Botanic Garden to tap into their expertise and presence in the Chicago metropolitan area to design our landscape concept.

While achieving a functional landscaping system, we would be able to directly screen different clones or hybrids/wild types of the most relevant plant species locally; measure their water use, biomass production, and rooting depth; and determine their ability to achieve a few main functions (which may or may not be mutually exclusive):

- Suitability for use in green, natural storm water management systems.
- Survival with minimal detriment to erratic weather patterns such as droughts and flooding.
- Increase terrestrial carbon storage on site.

Storm water control by means of rain gardens has been proposed as a green alternative to traditional sewers; however, little information is available to clearly derive performance metrics and demonstrate the benefits of this proposed approach. This approach relies on the soil water storage capacity (a function of soil characteristics) and plant water use to minimize the amount of water that is sent to conventional sewer infrastructure. We know from our own research that certain trees (example: cottonwoods) are very adaptable water users and could be deployed in vegetative systems to control storm water, take up pollutants, and in the long term help increase, through the development of a strong root system, carbon sequestration in soil. How efficiently these plants adapt to conditions of intermittent flooding and drought will be critical to their surviving climate-change induced variations in weather events.

The ability of a plant to survive in a water-limited or water-rich environment depends on a number of behaviors (escape, avoidance, and tolerance). In many plants, larger and deeper root systems have been shown to correlate with more efficient water uptake and greater yield under drought stress. Deep rooting is fundamental to shield plants from dependence on dry surface

soil. Most native, drought resistant plants (such as prairie grasses) owe their survival in low-water environments at least in part to deep-reaching root systems. Cottonwoods, a common plant across the U.S., and a potential lignocellulosic biofuel feedstock, have an adaptive mechanism (development of deep roots to search for moisture in deep soil/groundwater) that allows them to avoid or minimize drought stress, and to survive periods of flooding. We believe that this mechanism is genetically enabled and environmentally controlled. By testing a number of plants of different genetic makeup, this project will also provide the basis for future research opportunities in the molecular basis for plant adaptation to water stress.

A-5.2 Technical Risks

This project will be relatively risk-free. Design of the storm water system may need to be revisited after data are collected.

A-5.3 Relevance to Argonne's R&D Mission

This project has links to two strategic areas: environmental sustainability and energy security. Adaptable ecosystems will be the basis for climate change resilience, and the information will be directly applicable to biofuel feedstock development, carbon offset assessment, and the development of a plant molecular biology program.

A-5.4 Environmental Benefits

Environmental benefits are a function of current and future land use and management practices. On an acre basis, the tree farm may be able to treat up to 900,000 gallons of storm water per acre (average of years 1-5) with a peak of over 2 million gallons per acre at maturity (years 5 and beyond). While producing an estimated 2-5 tons/acre/yr, soil carbon could be increased by 0.1 and 2.3 Mg of carbon/acre-yr,[5] depending on how the site is transitioned from one use to the other.

A-5.5 Estimated Schedule and Cost

The project will engage Argonne's FMS Natural Resources Manager, Energy System Division research staff, and Biology Division terrestrial ecology research staff. Two months and $50,000 are required for project planning. Implementation of the project will require 18 months and $400,000. Annual maintenance and analysis will require $150,000.

Once implemented, it is expected that this planting will have a life expectancy of >20 years.

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[5] Sources: Lemus, R.; Lal, R. Bioenergy crops and carbon sequestration. *Crit. Rev. Plant Sci.* **2005**, 24, 1–21.

Kim, H.; Kim, S.; Dale, B. E. Biofuels, land use change, and greenhouse gas emissions: Some unexplored variables. *Environ. Sci. Technol.* **2009**, 43 (3), 961–967.

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A-6 Fuel cell applications with waste heat recovery, thermal storage, and renewable fuels

Installation of a natural-gas-powered fuel cell at the Center for Nanoscale Materials (CNM) will provide a working system to study the effectiveness of alternate fuel sources and varying methods of waste heat reclamation and storage.

A-6.1 Project Description

The project would focus on the installation of a 300 to 400 KWe natural gas fuel cell as described in the report, “Feasibility of Deploying a Combined Heat and Power Fuel Cell System at Argonne’s Center for Nanoscale Materials,” dated May 12, 2010. This report concluded that a natural gas fuel cell could be installed at the CNM facility to provide an economical source of reliable electricity and heat for the facility. Driving the economics is the ability to integrate the fuel cell’s low-temperature waste heat stream into the existing CNM heat recovery system, thereby creating a laboratory facility heated totally with waste heat sources. This project would entail the construction of an economically self-sustaining system to advance deployment of fuel cell technology while supporting research in alternate fuel sources and waste heat reclamation. It is anticipated that operation of the fuel cell during this research will generate sufficient usable electricity and heat to offset the base system’s construction cost over a reasonable period of time.

Areas of research will include the study of renewable biogas and natural gas fuel mixtures to determine optimal mixture ratios for overall system performance under varying operating parameters. Biogas will be mixed with the natural gas to study the fuel cell’s ability to generate electricity with fuels of varying heating value.

The key to economic viability of stationary fuel cells rests in the critical use of electricity and the recovery and reuse of its waste heat stream. The generated electricity will provide a secure source to power critical electrical laboratory and safety systems. In addition, full utilization of the low-temperature waste heat nearly doubles the total useful energy output of the fuel cell, greatly enhancing the economics of the system. Whereas high-temperature waste heat technology is mature, technology for low-temperature sources is in its infancy.

Two areas of application will be investigated: The first will examine methods for direct waste heat utilization, including methods of storage that leverage the economics of natural geological formations such as existing aquifers or the thermal mass associated existing building structures and their subsoil constituents. The second area will focus on the creation of hybrid systems that apply other technologies such as organic Rankine cycle turbines for additional electrical power generation and liquid and solid desiccant chillers that utilize waste heat to provide building and process cooling. Utilizing the CNM as the test area has the added benefit of easy integration into the existing Area 400 site waste heat reclamation systems, permitting additional investigation into various strategies and combinations of waste heat utilization on large-scale low-grade waste heat distribution networks.

Locating this project at the CNM provides significant economic advantage, since the building was constructed to accommodate the addition of a future fuel cell and much of the utility infrastructure, gas source, heat exchangers, piping, pumps, etc., are in place to reduce the installation effort and associated costs. Analysis indicates that the construction cost of the base system, as described in the report, can be recovered in 10 to 12 years, based on anticipated energy savings from normal fuel cell operation.

A-6.2 Technical Risks

Technical risks include the potential for mechanical equipment failure. Program risks include unanticipated delays in fuel cell delivery or schedule delays due to design review and permitting.

A-6.3 Relevance to Argonne's R&D Mission

The proposed project takes advantage of Argonne's long-standing fuel cell development and testing program.

A-6.4 Environmental Benefits

Due to their high efficiencies, fuel cells emit CO_2 at rates 6-18% less than the ComEd utility rate and 9-35% less than PJM's. The use of fuel cell waste heat will lead to additional reductions in greenhouse gas emissions because of a reduction in Argonne steam demand. These data are displayed in the following table:

Table A – 1: From the Argonne report, "Feasibility of Deploying a Combined Heat and Power Fuel Cell System at Argonne's Center for Nanoscale Materials," dated May 12, 2010

Emissions Gas	Emissions (lb/MWh)				Fuel Cell Emissions (lb/MWh)	
	ComEd	PJM (4th Qtr 2009)	US Grid (2005)	Heat from Argonne Steam Plant (NG fuel)	Model 400 (electricity & heat)	DFC300 (electricity & heat)
Carbon dioxide	703	1230	1329	485	1,120	980
Nitrogen oxides	1.03	2.0	1.9	0.404	0.036	0.01
Sulfur dioxide	3.41	7.2	5.3	0.002	~0	0.0001

A-7 Development and testing of carbon-free heating and cooling through solar energy collection and storage

A project to develop, demonstrate, and test medium-scale carbon-free heating and cooling technology based on concentrated solar power (CSP) and high-temperature energy storage is proposed. This work will help explore the potential of concentrated solar power under Midwest climate conditions.

A-7.1 Project Description

This project is to study, design, implement, and test a zero-emission, medium-scale (~6 MW) concentrated solar power facility with high-temperature thermal energy storage at Argonne. The goal is to test the viability of this form of sustainable energy delivery in this region of the U.S. The facility will collect ~6-MW day-night average solar thermal energy with an optimized array of collectors with net surface area of 10 acres covering ~30 acres of available land at ~33% coverage near the Argonne steam generating plant. These numbers are based on the NREL CSP resource map for this region (3.6 kWh per day per square meter or 600 kW per

acre of collector surface area). To average over day-night and day-to-day variations, a large-capacity high-temperature thermal storage facility will be an essential feature of the complex.

The Argonne CSP complex will be used to provide steam for building heating, especially in the cold seasons, and chilled water for programmatic requirements and building air conditioning in the warm seasons. This emission-free heating will replace 6 MW of thermal energy that has historically been provided by coal or will eventually be provided by natural gas through the planned Argonne combined heat and power (CHP) plant in cold seasons and will replace a corresponding amount of electrical power used to drive chillers in the 300 area in warmer seasons. Building and process heat will be supplied directly by steam-turbine-driven chillers when needed. A study will determine if adsorption or absorption chillers driven by the lower quality waste heat is economically and environmentally justified.

The first step of this project is to evaluate the economic and environmental benefits of an optimized implementation in the specific context of Argonne's climate and energy mix. In particular there are expected benefits from the direct use of the thermal energy without the inefficiency of conversion to electricity. This initial study will evaluate the benefits of this direct use of solar thermal energy in the Argonne area relative to other renewable resource options such as bio-mass, solar photo-voltaic panels, and wind energy. The use of large-scale, high-temperature, thermal energy storage by means of molten salts, for example, is already a demonstrated viable technology and one outcome of this project will be further optimization of the necessary fluids and materials.

Initial evaluation of the many choices of solar energy collectors is also required. Parabolic troughs, Fresnel mirrors, and Winston compound-parabolic collectors are among the options to be evaluated for performance in this region. Additionally, there are non-tracking and single- or dual-axis trackers to be considered. The Argonne CSP facility can provide a valuable test bed for emerging approaches for Midwest applications.

A-7.2 Technical Risks

The main risk is associated with the economics of CSP technology in the Midwest. This risk will be managed by detailed systems engineering up front. It is clear that existing CSP and high-temperature energy storage technologies can be implemented on a scale to greatly reduce CHG emission. The benefits of large-scale energy storage for load leveling to reduce peak energy demands will partially offset the relatively low solar power available in the Midwest. The risks will be further minimized through partnerships with industrial developers with Midwest experience.

A-7.3 Relevance to Argonne’s R&D Mission

Development and implementation of reliable and economical medium to large scale solar-thermal power systems require complex systems engineering that Argonne excels at. Moreover, Argonne has active programs in thermal energy storage and energy conversion technology.

A-7.4 Environmental Benefits

Carbon dioxide emission savings will depend on the mode of operation, but the solar production of 6 MW of thermal energy would save 10,000 tons of CO_2 that would otherwise be emitted by 1.5 million therms of natural gas at the Argonne CHP plant. This is 17% of the present CO_2 emission from natural gas at Argonne, and 3% of the overall greenhouse gas emission from the laboratory.

A-7.5 Estimated Schedule and Cost

Systems engineering studies and existing technology evaluation, including evaluation of the optimal method of integrating these approaches with the present Argonne energy usage mix, would take up to 2 years. A small-scale prototype with a capacity of ~1-MW thermal could be initiated during the first year if the prospects look favorable, and the completion of this prototype could be anticipated by the end of the third year. The cost of this first phase (systems engineering and planning plus the 1-MW prototype) is estimated to be about $2.3M.

Medium-scale solar thermal energy farms with high temperature energy storage cost in the neighborhood of $1.3M per installed MW of collection and storage capacity. Based on this rule of thumb, the system cost for the additional 5-MW capacity will be in the range of $6.5M.

The overall savings in energy cost per year would be about $0.8M per year.

Overall, the complete project is expected to require about 10 years to complete. Since the system is inherently modular, capacity could be increased incrementally through this period, and improved technologies could be implemented in successive modules. The design lifetime of the equipment is expected to be 20 years or more. Operations and maintenance costs should be in the range of 10-20% of the annual savings on natural gas or coal.